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PUBLICATIONS OF THE Astronomical Society of the Pacific.

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JANUARY 1, 1895.

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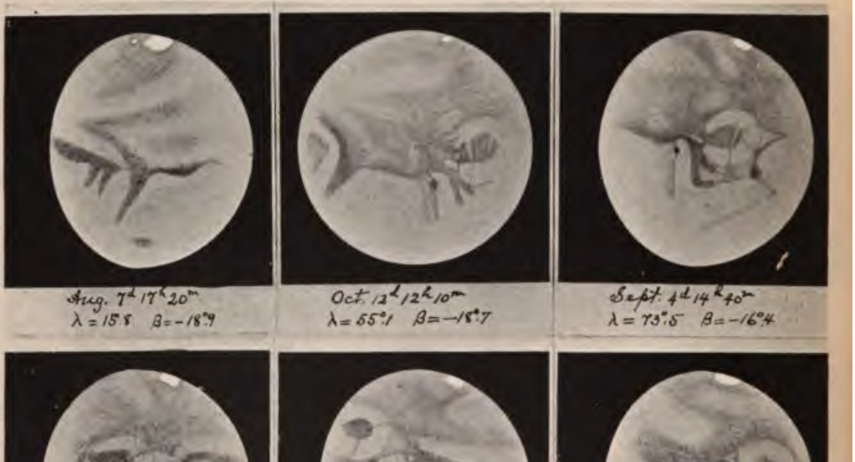

Aug. 7^d 17^h 20^m
$\lambda = 15.8 \quad \beta = -18°.9$

Oct. 12^d 12^h 10^m
$\lambda = 55°.1 \quad \beta = -18°.7$

Sept. 4^d 14^h 40^m
$\lambda = 73°.5 \quad \beta = -16°.4$

Aug. 31^d 14^h 0^m
$\lambda = 100°.9 \quad \beta = -16°.6$

Aug. 29^d 15^h 25^m
$\lambda = 140°.1 \quad \beta = -16°.7$

Aug. 24^d 16^h 15^m
$\lambda = 199°.1 \quad \beta = -17°.1$

Oct. 25^d 11^h 42^m
$\lambda = 294°.1 \quad \beta = -20°.6$

Aug. 15^d 17^h 6^m
$\lambda = 296°.4 \quad \beta = -18°.0$

Aug. 8^d 14^h 25^m
$\lambda = 323°.7 \quad \beta = -18°.7$

PLATE C$_3$

MARS, 1894.

By W. W. CAMPBELL, LICK Observatory.

PUBLICATIONS

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SPECTROSCOPIC OBSERVATIONS OF NEBULÆ, MADE AT MOUNT HAMILTON, CALIFORNIA, WITH THE 36-INCH REFRACTOR OF THE LICK OBSERVATORY [BY J. E. KEELER].

[From the *Publications of the Lick Observatory*, Vol. III, 1894.]

Reviewed by Professor B. HASSELBERG, Royal Academy of Sciences, Stockholm, Sweden.

In the second volume (1890) of the *Publications* A. S. P., Professor KEELER gave a preliminary account of his spectroscopic determinations of the motions of some planetary nebulæ in the line of sight. The results there laid before the astronomical public are very remarkable indeed, being not only the first successful attempt in this direction, but also and above all distinguished by so great an accuracy, that they stand in every way unequalled by any observations of this class as yet known to science. It is, then, obvious that a detailed account of these researches should be waited for with very great interest, and, in the above-named memoir, Professor KEELER has given such an account, of which a succinct abstract may be acceptable to the readers of the present periodical.

As well known, the gaseous character of the spectra of planetary nebulæ was discovered by HUGGINS as early as the year 1864. Astronomers are also well acquainted with the results of his researches at this time about the chemical origin of the observed nebular lines, and with the doubts which subsequently arose regarding the assumed relation of the chief line to the spectrum of nitrogen, and the reasons upon which these doubts were founded. Whereas the chemical interpretation of the third line has proved fully exact, it was soon found that the chief line could have no connection with nitrogen, but was of the same enigmatical character as the second line and the lines which are met with in the spectra of several other cosmical phenomenon, such as the aurora, the solar corona and prominences. In this state of the question, Lockyer, in connection with his theory of the heavenly bodies, expressed the opinion that the chief nebular line belonged to magnesium, and that it was the remnant of the known bright fluting in the green, which is the most prominent feature of the flame spectrum of this metal. It does not seem improbable that this suggestion might have met with a certain amount of credit among spectroscopists, had not the utterly different appearance of the magnesium fluting, as compared with the nebular line, made the matter doubtful from the outset. But this circumstance induced astronomers to inquire more closely into the question of the coincidence or non-coincidence of the nebular line with the lower edge of the magnesium fluting, and as in this respect the repeated researches of Huggins showed, unmistakably, that the nebular line was the more refrangible one, the question seemed decided. From a renewed discussion of previous observations on the position of the chief nebular line, up to 1870, Lockyer nevertheless concluded that the coincidence in question was perfect, and his own observations of the *Orion* nebula, with a spectroscope of the old Kirchhoff form, only confirmed this conclusion. But it is obvious that a spectroscope of this description is much too crude for the unambiguous distinction between spectrum places of so great vicinity as here concerned.

At the request of Huggins, Professor Keeler was induced to take up the question with the great instrumental means of the Lick Observatory. The examination of the nebulæ G. C. 4234 (Σ 5) and G. C. 4373, with a diffraction grating of 14438 lines to the inch, fully confirmed the opinion of Huggins in regard to the non-coincidence of the nebular line with the terminal line of the magnesium fluting. But, besides this, such an appreciable difference in the positions of the chief line in the two nebulæ was observed, that a considerable motion in the line of sight of one or both objects must be assumed. This circumstance induced Professor Keeler to extend the investigation to a great many nebulæ, of which ten presented the chief line bright enough for an accurate determination of its place. From the mean of these ten nebulæ the wave-length $\lambda = 5005.68$ in ÅNGSTRÖM'S Units (A. U.) resulted—deduced, of course, under the provisional supposition that the motions of the single nebulæ compensated each other in the mean. After a determination of the radial velocity of the *Orion* nebula, in the winter of 1890–91, by means of its hydrogen line, the normal position of the chief line was corrected to $\lambda = 5005.93$.*

After these introductory remarks, Professor KEELER, in the next two chapters (II and III) gives a detailed description of the apparatus employed and of very elaborate experiments on instrumental errors. The star spectroscope used in connection with the 36-inch refractor was made by BRASHEAR, after drawings by Professor KEELER himself. For the particulars of its construction the original memoir must be consulted, it being sufficient here to mention only the most prominent features. Thus, the objectives of both collimator and observing telescope were made of Jena glass, with clear apertures of $1\frac{1}{2}$ and focal lengths of 20 inches. A second observing telescope of only 10 inches focus is also provided. The dispersive part of the instrument consists of a ROWLÁND grating with a ruled surface of $2\frac{1}{16}$ x $3\frac{3}{16}$ inches and 14438 lines to the inch. This grating can, if desired, be changed for a prism of 30°, 60°, or for a compound one of about three and a half times the dispersion of the 60° prism. The whole instrument is connected with the refractor by means of two heavy brass tubes, inserted by clamps in a large collar surrounding the tailpiece of the telescope tube, and provided with position-circle and slow motion. All the appliances necessary for adjustment of the spectroscope are provided.

For the determination of spectrum places by relative measurements, a micrometer, the value of a revolution of which is 3′ 10″.8, is adapted to the observing telescope; and, besides this, a 60° reflecting prism permits the introduction of comparison spectra. But absolute determinations of wave-lengths are also possible, the grating-table being to this end connected with a graduated circle divided on the edge to 10′, and which, by two verniers can be read to 10″.

Before employing the above-described instrument in the delicate observations here concerned, the author made very careful researches on the errors which may possibly arise through imperfect adjustment and other causes. In this regard the arrangement of the comparison apparatus is of the first importance, it being next to certain that a great part of the discrepancies of former observations among themselves is to be attributed to imperfections in this regard. The essential condition that the same lines in the direct and reflected spectrum shall always be in exact coincidence, was insured here by causing the two pencils of rays to pursue the same path in the instrument; and different trials with the spectra of sodium, magnesium and solar light, showed that a perfect adjustment was attained. That the usual adjustments of the collimator with respect to the optical axis of the great telescope, the micrometer wires, and the slit, in relation to the focal planes of the observing telescope and the collimator, were carefully effected, scarcely needs to be pointed out. Further, the influence of flexure was tested by measuring the distance $\Delta\lambda$ between the lead line λ 5005.6 and the chief line in the *Orion* nebula, in four different positions of the spectroscope, obtained by rotating the whole about the axis of the refractor. The results were :

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* According to ÅNGSTRÖM'S scale. On account of circumstances well known to spectroscopists, Professor KEELER, in his subsequent researches, has adopted the scale of ROWLAND.

Position-circle at 30°	$\Delta\lambda$ = 2.09 (A. U.)
120	.15
210	.03
300	.01
30	.10
	2.08 ± 0.02

It is evident from these figures that no appreciable error due to flexure exists in these visual observations. As further repeated determinations of the distance of the chief nebular line in the spectrum of G. C. 4390 from the above-named lead line, executed both with the grating and with the compound prism, were in satisfactory accordance, it is plain that systematic errors of any sensible amount could be regarded as not existing.

The author next passes to the description of his method of observation. In all measurements of the position of the spectral lines in the nebulæ the ROWLAND grating was used. The observations, which were mainly differential, the nebular lines being referred to suitably situated metallic lines introduced by the comparison prism, were taken either in the third or fourth order.

The slit was narrowed so that the bright lines of the nebula or the comparison spectrum equalled the apparent width of the micrometer wire, and the settings made by occulting the lines by the latter. Any possible personal error in setting the micrometer was eliminated by executing the observations alternately on opposite sides of the instrument. For the reduction of the measured distances to differences of wave-length, the following values of the micrometer revolution, obtained by measures in the solar spectrum, were used :

At.	III Order.	IV Order.	
D	$1^r.0 = 3.29$		
b	3.60	2.10	
Neb. 1	3.71	2.21	A. U.
Neb. 2	3.73	2.24	
H_β	3.75	2.28	

As comparison lines in the differential measures he used, for the chief nebular line, a very thin and sharp line in the lead spectrum at λ 5005.6, and the marginal line of the magnesium fluting at λ 5007.5, between which the nebular line usually lies; and for the second nebular line he used the iron line at λ 4957.6. The use of the magnesium fluting was afterwards abandoned, experience showing that the accuracy of the observations was not impaired by referring them only to the lead line. The exact positions of these lines on ROWLAND'S scale, as determined in his laboratory by Mr. JEWELL and adopted by the author, are the following :

Magnesium fluting, edge, λ = 5007.473
Pb = 5005.634
Fe = 4957.634

Of these lines that of iron is double, with the components 4957.786 and 4957.482; but as they could not be separated with the slit-width used in nebular observations, the measurements refer to the center of the pair.

In order to show the accuracy of the measures, various examples of observations are given in the fourth and seventh chapters. Part of these are observations of planets and stars made during the course of the observations of nebulæ, as a check of the instrumental adjustments. Of these measures it may be convenient here to give the following as specimens of the exceedingly high accuracy attained by the author. If we denote by λ, n, the wave-length and micrometer reading for the observed line in the spectrum of the heavenly body, and by λ_0, n_0, the corresponding quantities for the comparison line, then we have

$$\lambda = \lambda_0 + r\ (n - n_0)$$

where r denotes the value of the micrometer revolution as given above.

I. 1890 JULY 17. G. C. 4390 (Σ 6).

COMPARISON OF THE CHIEF LINE WITH Pb AND Mg, IV ORDER.

Neb.	Pb.	Δ	Neb.	Mg.	Δ
$4^r.72$	$4^r.12$	+ 0.60	$4^r.76$	$4^r.98$	− 0.22
.75	.13	.62	.70	.96	.26
.74	.12	.62	.71	.95	.24
.72	.08	.64	.69	.93	.24
.70	.09	.61	.74	.92	.18
.67	.01	.66			
.78	.14	.64			
		0.627			− 0.228

0.627 r =	1.39 A. U.	− 0.228 r =	− 0.51 A. U.
Pb λ :	5005.63	Mg λ :	5007.47
Neb.	5007.02		5006.96

Mean, 5006.99
Earth's motion, − 0.17
∴ Neb. λ = 5006.82

II. OBSERVATIONS OF *VENUS*.

	Displacement of D.	Observed Motion.	Calculated Motion.	C.-O.
1890 Aug. 16	−0.070	−7.3	−8.1	−0.8 miles
22	−0.085	−8.9	−8.2	+0.7
22	−0.072	−7.5	−8.2	−0.7
30	−0.070	−7.3	−8.3	−1.0
Sept. 3	−0.079	−8.2	−8.3	−0.1
4	−0.079	−8.2	−8.3	−0.1
1891 Mch. 21	+0.062	+6.5	+7.9	+1.4
Apr. 3	+0.061	+6.4	+7.7	+1.3

α *Bootis.*

	Displacement of D.	Observed Motion.	Earth's Motion.	Motion of Star referred to Sun.
1890 Apr. 10	−0ʳ.044	− 4.6 miles	− 0.6	−4.0
Aug. 7	+0.100	+10.4	+14.3	−3.9
15	+0.089	+ 9.3	+13.3	−4.0
1891 Mch. 16	−0.106	−11.1	− 7.3	−3.8
20	−0.121	−12.7	− 6.3	−6.4
Apr. 2	−0.053	− 5.5	− 2.9	−2.6
29	−0.003	0.0	+ 4.3	−4.3
May 8	+0.024	+ 2.5	+ 6.6	−4.1
14	+0.031	+ 3.2	+ 8.0	−4.8
				−4.2 ±0.2

The above specimens are sufficient to show at the same time the great accuracy of the measures and their freedom from appreciable errors by want of adjustment of the spectroscope. Indeed, a probable error of only ±0.2 miles for the radial velocity of a star is an accuracy which hitherto has only been reached in the Potsdam photographic determinations, but which, in visual observations, could hardly have been hoped for.

The chemical origin of the chief nebular line being unknown, its normal position, *i. e.*, the position which it would have if the observer and the nebula were at rest relatively to each other, cannot be determined unless the motion can be ascertained in some nebula with help of the third line, which undoubtedly belongs to hydrogen. Hence, the determination of the radial velocities of the nebulæ depend on such a measurement.

Among the nebulæ observed by the author, only two, the *Orion* nebula and G. C. 4390, were bright enough to permit a direct comparison with the hydrogen spectrum. On this account it seems convenient to give here in full the determinations obtained for these two objects.

(*a*) THE *ORION* NEBULA.

The observations were always made in the same part of the nebula immediately preceding the trapezium, in order to have them all undisturbed by any possibly existing rotary motion of its different parts. The results are embodied in the following tables :

I. Position of the Chief Line.

		Order.	Distance from Pb. Line.	Observed λ	Correction for Earth's Motion.	λ
1890 Feb.	13	IV	+2.13 A.U.	5007.76	−0.39	5007.37
	13	III	1.92	07.55	−0.39	.16
Mch.	20	IV	2.08	07.71	−0.43	.28
Oct.	10	IV	1.32	06.95	+0.39	.34
	16	IV	1.51	07.14	+0.36	.50
	17	IV	1.34	06.97	+0.36	.33
	17	III	1.39	07.02	+0.36	.38
	23	IV	1.49	07.12	+0.33	.45
	23	III	1.48	07.11	+0.33	.44
	30	IV	1.38	07.01	+0.30	.31
	30	III	1.34	06.97	+0.30	.27
1891 Jan.	23	III	2.04	07.67	−0.30	.37
	23	IV	1.97	07.60	−0.30	.30
	26	IV	2.02	07.65	−0.31	.34
	28	IV	2.09	07.72	−0.32	.40
Feb.	12	IV	2.08	07.71	−0.39	.32
Apr.	3	IV	+2.04	07.67	−0.40	.27
						5007.34 ± 0.013

II. Motion of the Nebula from Comparison of the Third Line with H_β.

		Order.	Displacement of Nebular Line.	Observed Motion. Miles.	Earth's Motion. Miles.	Motion of Nebula referred to Sun. Miles.
1890 Oct.	16	III	$-0^{\mathrm{r}}.019$	− 2.7	−13.6	+10.9
	23	III	− .003	− 0.4	−12.4	12.0
	23	III	− .019	− 2.7	−12.4	9.7
	30	III	− .050	− 7.2	−11.2	4.0
1891 Jan.	23	IV	+ .241	+19.4	+11.0	8.4
	23	III	+ .191	+25.8	+11.0	14.8
	26	III	+ .125	+16.9	+11.6	5.3
	28	III	+ .233	+33.5	+12.0	21.5
Feb.	12	IV	+ .307	+26.9	+14.5	12.4
	12	III	+ .183	+26.3	+14.5	11.8
Mch.	6	IV	+ .284	+24.9	+16.2	8.7
	18	IV	+ .338	+29.6	+16.1	13.5
	20	IV	+0.300	+26.3	+16.1	10.2
					Mean,	11.0±0.8

The nebula thus receding from the solar system at a rate of 11 miles, the third line is displaced toward the red by nearly 0.29 A. U., and also the chief line by nearly the same amount. Thus, its normal position would be

$$5007.34 - 0.29 = 5007.05.$$

(*b*) G. C. 4390.

On account of the great brightness of this nebula, the position of the chief line could be determined very accurately, as will be seen from the following table, in which the observed values have been reduced by referring the line both to the lead line and to the magnesium fluting.

I. Position of the Chief Line.

	Observed λ.	Red. to Sun.	λ
1890 July 10	5007.06	— 0.12	5006.94
17	06.99	— .17	.82
24	07.18	— .22	.96
25	07.14	— .22	.92
25	07.18	— .21	.97
31	07.16	— .26	.90
Aug. 1	07.14	— .27	.87
7	07.18	— .29	.89
8	07.25	— .30	.95
1891 Apr. 29	06.53	+ .34	.89
May 8	06.59	+ .30	.89
14	06.56	+ .26	.82
22	06.58	+ .22	.80
			5006.89

II. Comparison of the Third Line with Hβ, IV Spectrum.
Nebular Line Displaced Toward Red.

1891 May 21. Neb. Line — Hβ.	May 22. Neb. Line — Hβ.
$-0^{r}.157$	$-0^{r}.183$
.176	.155
.141	.188
.201	.231
.201	.154

1891 May. 21. Neb. Line — $H\beta$.	May 22. Neb. Line — $H\beta$.
.163	.160
.146	.173
.144	.120
.196	.176
.167	.091
0.169	— 0.163

∴ Observed motion,	— 14.8 miles.	— 14.3
Earth's "	— 8.0	— 8.0
Nebula to Sun,	— 6.8	— 6.3

Mean, — 6.55 miles.

From this velocity towards the solar system it follows that the chief line is displaced towards the violet by

0.18 A. U.,

and that the normal position is

5006.89 + 0.18 = 5007.07.

The close agreement between this value and that derived from the *Orion* nebula is indeed highly satisfying, and the best proof of the truly surprising accuracy attained by the author in his observations.

It would be superfluous, in the present abstract, to transcribe more specimens of the rich material of observations accumulated by the author in his memoir. But, on comparing the resulting wave-lengths for the chief line in the different nebulæ as referred to the Sun, differences are found which many times exceed the small probable errors. These differences can only depend upon radial motions of the nebulæ relatively to the solar system. By comparison with the normal position of the chief line as deduced above, it is therefore possible to calculate the velocities of these motions. The results of such a determination for the nebulæ of sufficient brightness to permit a satisfactory measurement of the chief line are given in the following table :

Nebula.	λ	Displacement.	Motion, miles.
Orion.	5007.34 ± .013	+ 0.29 ± .02	+ 11.0 ± 0.8
G. C. 826	06.88	— 0.17	— 6.3
G. C. 2102	07.15 ± .04	+ 0.10 ± .05	+ 3.7 ± 1.8
G. C. 4234 (Σ 5)	06.48 ± .02	— 0.57 ± .03	— 21.3 ± 1.3
G. C. 5851	06.19	— 0.86	— 32.0
G. C. 4373	05.97 ± .04	— 1.08 ± .05	— 40.2 ± 1.8
G. C. 4390 (Σ 6)	06.89 ± .01	— 0.16 ± .03	— 6.0 ± 1.2
N. G. C. 6790	07.86	+ 0.81	+ 30.1
G. C. 4510	06.77	— 0.28	— 10.4 ± 2.8
G. C. 4514	06.96 ± .02	— 0.09 ± .03	— 3.3 ± 1.5
N. G. C. 6891	07.73	+ 0.68	+ 25.3 ± 4.0
G. C. 4628	06.22 ± .04	— 0.83 ± .05	— 30 9 ± 1.8
N. G. C. 7027	07.22 ± .01	+ 0.17 ± .03	+ 6.3 ± 1.2
G. C. 4964	06.86	— 0.19	— 7.1 ± 3.0

The positive sign signifies recession, the negative approach. The probable errors are combinations of the corresponding quantities for the measurements and for the normal position of the chief line. The author divides the nebulæ in two groups: very bright (I), and bright (II), and finds

	Probable Error of Displacement.		No. of Observations.
I	ε = ± 0.058 A. U.	= ± 2.2 miles	1
	= .046	1.7	2
	= .039	1.5	4
II	ε = ± 0.104	± = 3.9	1
	.077	2.9	2
	.058	2.2	4

From the above table it is seen that motions of approach preponderate. This is only a consequence of the fact that the greater part of the examined nebulæ are situated in the same region of the sky as the apex of the solar motion.

It cannot be but regretted that determinations of the places of nebulæ, with any exactitude approaching that obtained for the stars, are hitherto almost absolutely wanting. Thus every idea, not only of their parallaxes, but also of their proper motion, is, with exception of perhaps the sole instance of the *Trifid* nebula, for a long time to come, out of question. And yet the knowledge of these quantities is the *conditio sine qua non*, in combination with the spectroscopically determined radial velocities, to get any notion of their real movements. On reflecting upon these matters, one is almost inclined to consider the employment of the great refractors of to-day in prolonged observations of the old members of the planetary system of asteroids, comets, and such, as abuse of means; because in most cases, for researches of this class, instruments of medium size would suffice; whereas, for a systematic scrutiny of the nebular world, only from the greatest optical powers can be expected any progress worthy of consideration.

Besides the position of the chief line, that of the second line, in a number of nebulæ, has been determined by comparison with the iron spectrum, or by measuring its distance from the chief line by means of the graduated circle of the spectroscope. In the former case the apparent position was first corrected for the orbital motion of the Earth, and then, by means of the known radial motion of the nebula, reduced to its normal value. In the second case the final result is deduced by subtracting the measured interval from the normal place of the chief line. Thus the following results were obtained :

(*a*) NORMAL POSITION OF THE SECOND NEBULAR LINE FROM COMPARISON WITH THE IRON LINE 4957.63.

Nebula.	λ	Motion of Nebula.	Correction for Motion.	Normal λ
Orion	4959.33	+ 11.0 miles	− 0.29	4959.04
G. C. 2102	59.06	+ 3.7	− 0.10	58.96
G. C. 4373	57.98	− 40.2	+ 1.07	59.05
G. C. 4390	58.90	− 6.0	+ 0.16	59.06
N. G. C. 7027	59.15	+ 6.3	− 0.17	58.98
				4959.02
				± 0.04

(*b*) NORMAL POSITION OF THE SECOND NEBULAR LINE DEDUCED FROM THE POSITION OF THE FIRST LINE.

Nebular.	λ
Orion	4958.92
G. C. 4373	59.14
G. C. 4373	59.01
G. C. 4390	59.16
N. G. C. 7027	58.98
N. G. C. 7027	59.23
	4959.07
	± 0.03

The agreement is, as seen, in every way excellent.

In virtue of the above-exposed results, the validity of LOCKYER'S opinion regarding the relation of the chief nebular line to the green fluting of the magnesium flame spectrum is easily tested. The normal position of the nebular line is, as we have seen,

From observations of the *Orion* nebula $\lambda = 5007.05$
From observations of G. C. 4390 $.07$
5007.06

Whereas the position of the edge of the magnesium fluting, according to Mr. JEWELL, is

$$\lambda = 5007.47.$$

The difference, 0.41 A. U., is about fourteen times greater than the probable error of observation, and must therefore, on account of the absence of sensible systematic errors in the observations, be considered as real. This fact is alone sufficient to make any connection between the two impossible. It is much more the case since, even on the supposition of exact coincidence between two single lines in a celestial and metallic spectrum, the reality of a connection between them is therefore by no means proved. To make such a connection, on the whole, probable, not only the position, but also the external features of the compared lines must, of course, be identical. In the present instance, however, the numerous observations and experiments, which the author has instituted with the view to test this question, show a decidedly negative result; and hence the observations of the hazy character of one side of the chief nebular line formerly recorded must have resulted from instrumental imperfections.

After an exposition of some views regarding the origin of the nebular lines and the constitution of the nebulæ in general, founded upon the observations detailed in the preceding chapters, the author finally sums up the results to which his researches have led him. The essential part of these results has, it is hoped, been sufficiently pointed out in the preceding pages of this brief extract. For the great many spectroscopic and other details contained in Professor KEELER'S memoir, the original must be consulted. The reader will then find a rich reward and assuredly agree with the present writer in congratulating Professor KEELER on having made, in this work, the first really important progress in a domain of the spectroscopy of precision in which the most eminent spectroscopists have hitherto in vain exerted themselves.

STOCKHOLM ACADEMY OF SCIENCES. December, 1894.

PHOTOGRAPHS OF THE SUN AT MT. HAMILTON.

By Edward S. Holden.

The original programme of work at the Lick Observatory included making daily photographs of the Sun with a 40-foot photoheliograph.*

Some attempts to begin such a series were made in the years 1888–1892. In 1893 Mr. Perrine, Secretary of the Observatory, volunteered to undertake this work. Since that time we have a very complete record of Sun-spots. As no publication regarding this series of photographs has yet been made, I have asked Mr. Perrine to prepare the following memorandum. The available force of the Observatory is not now sufficient to make the necessary measures and reductions of these negatives. The photographs remain on file at the Observatory and they, or copies of them, are at the disposal of any astronomer, or Society, who may have the disposition to measure and discuss them. In general, the negatives are promptly developed and examined. The situation of the photoheliograph is not very favorable, but many of these negatives show fine definition and can be advantageously enlarged 5 or 6 diameters.

MEMORANDUM ON NEGATIVES OF THE SUN TAKEN WITH THE PHOTOHELIOGRAPH IN 1893–94.

The objective was placed in position and the first Sun photographs taken July 8, 1893. Between that date and December 15, 1894, exposures were made on 362 days. The days omitted include, besides cloudy ones, absences of 42 days. The number of days available would be materially increased if the photoheliograph were so situated as to receive the Sun's rays earlier in the morning and later in the afternoon.

About 950 negatives have already been made, of which something like 800 have been kept. The aim has been to select a pair of the best for each day. If only two were taken in a day, *both* were kept. If more were taken, then duplicates of the best were selected (for each of the hours, if exposures were made more than once a day) and the rest presented to the Astronomical Society of the Pacific, or destroyed. When practicable, duplicate negatives have been made as a check against imperfections in the film.

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* *Publications* A. S. P., Vol. IV, page 143.

The objective is of 5 inches aperture, but is stopped down to 3 inches, and the focal length is approximately 40 feet, giving an image of the Sun varying from $4\frac{3}{8}$ to $4\frac{9}{16}$ inches in size. The exposure is made by a shutter falling in front of the sensitive plate. This shutter has a horizontal slit with adjustable jaws, so that the width of the opening may be varied. In practice the correct exposure is gotten by using a width of the slit which varies from about $\frac{1}{4}$ inch in summer to $\frac{1}{2}$ inch in winter.

The length of the exposure varies from about $\frac{1}{400}$ second to $\frac{1}{800}$ second. The time at which the exposure is made, is gotten from a sounder in the dark room which gives the beats of the mean-time clock. These times are recorded to the nearest second. Very slow plates are used. C. D. PERRINE.

THE NEW STAR OF 1892.

By W. W. CAMPBELL.

We cannot doubt that all the stars are undergoing continual and progressive changes of condition. These changes are exceedingly slow and require long periods of time to become appreciable. In general, astronomers are not permitted to detect and record them. It is true that in the variable stars we observe rapid variations, both in brightness and in the appearance of their spectra; but so far as we know they occur in cycles. They repeat themselves and there are no evidences of permanent and progressive changes.*

The so-called "new stars" are in that respect an important exception. They change rapidly, both in brightness and physical condition, and in that fact lies their very great significance.

The interesting history of the new star in *Auriga* is well known. It appeared in December, 1891. Its spectrum was a very complex one, consisting of bright and dark lines and continuous spectrum. The star became too faint to be seen with the 36-inch equatorial in April, 1892. It was re-discovered in August, 1892, when it was of the 10th magnitude. Its spectrum consisted of a few isolated bright lines superposed upon a very faint continuous spectrum. It was no longer the spectrum of a star; it was the spectrum of a nebula, and as such it has continued to the present time. However, some interesting and significant changes have occurred in the past year. The intensities of at least two of the prominent bright lines have decreased very materially. They are the lines at wave-lengths 436 and 575. The variations will be realized best if we tabulate, as below, the intensities of the most prominent six lines as estimated in 1892, and as estimated on three occasions in 1894.

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* There is some evidence of variations in brightness of a few stars during historic times, but there is no evidence of a change in their physical condition, such as would be indicated by a change in their spectra.

		$H\gamma$	$\lambda 436$	$H\beta$	$\lambda 496$	$\lambda 501$	$\lambda 575$
1892.	Sept.	0.1	0.8	1	3	10	1
1894.	May 8.	0.1	0.3	1	3	10	0.4
1894.	Sept. 7.	0.1	0.2	1	3	10	0.4
1894.	Nov. 28.	0.1	0.1	1	3	10	0.3

It will be seen that the change in $\lambda 575$ is very decided and that the change in $\lambda 436$ is radical. The wave-lengths of both lines were observed in 1892 with comparative ease. They are now too faint for measurement. On the spectrum photographs taken early in September, 1892, the line $\lambda 436$ was by far the brightest line of all, *being certainly eight times as bright as* $H\gamma$. I have just secured another photograph of the spectrum (November 28), and it shows that $\lambda 436$ *is now fainter than* $H\gamma$. The intensities recorded in the above table show that the decrease has been gradual rather than sudden.

It is especially interesting that the lines $\lambda 436$ and $\lambda 575$ should be the ones to change. While the observations of the August, 1892, spectrum showed unmistakably that it was nebular, the lines $\lambda 436$ and $\lambda 575$ were not known to exist in the old nebulæ. However, photographs of nebular spectra soon showed the line $\lambda 436$ in five well-known nebulæ; and visual observations showed the line $\lambda 575$ in three well-known nebulæ. These lines were strong in the *Nova*, but relatively faint in the nebulæ. They have now become relatively faint in the *Nova!*

The spectra of the well-known nebulæ likewise have their anomalies. The lines $\lambda 447$ and $\lambda 469$, for instance, are very strong in some nebulæ, are very faint in others, and from some

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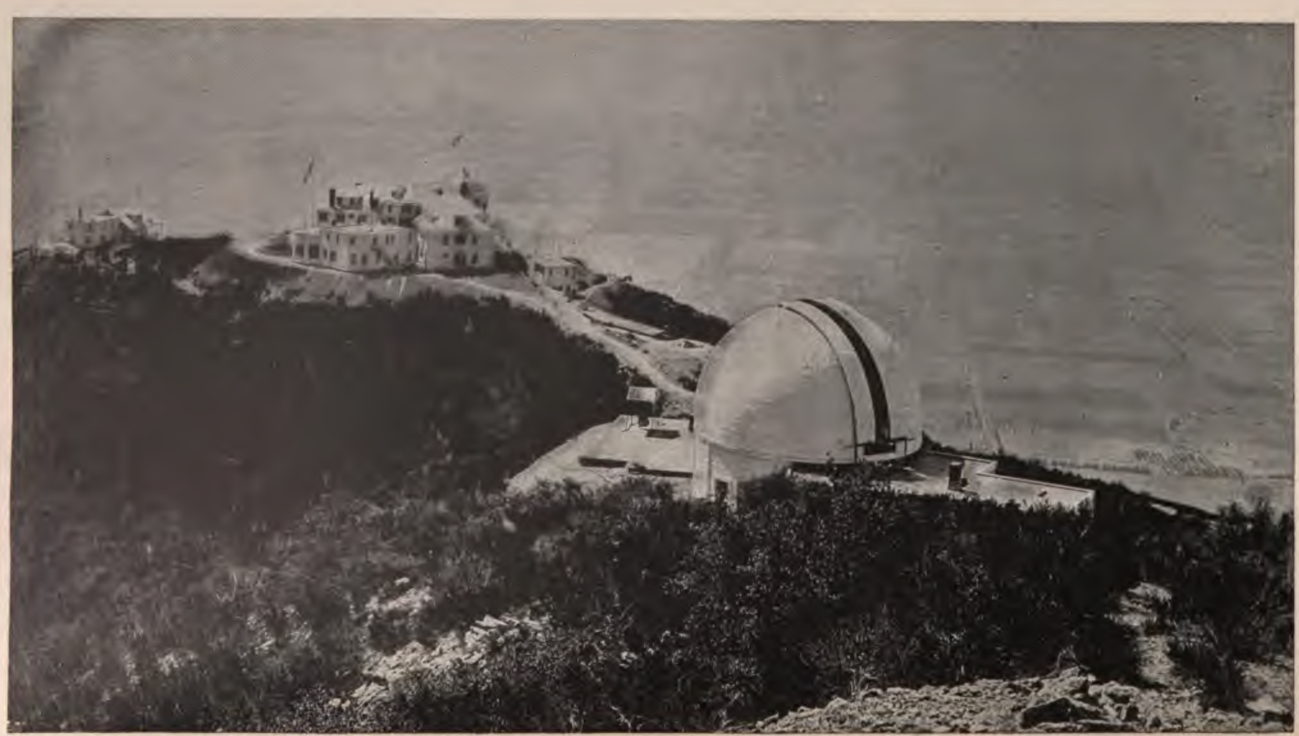

GENERAL VIEW OF ECHO MOUNTAIN, SHOWING ECHO MOUNTAIN HOUSE, CHALET, AND LOWE OBSERVATORY.
SAN GABRIEL VALLEY IN THE DISTANCE.

appear to be entirely absent. The new star seems to be rapidly losing its anomalies: its spectrum is not only nebular, but it is approaching the *average type* of nebular spectrum.

Measures of the positions of the lines λ496 and λ501 on September 7, 1894, gave a velocity of approach of 27 kilometers (17 miles) per second. Similar measures on November 28 gave a velocity of approach of 13 kilometers (8 miles).

THE SUN'S MOTION IN SPACE.

By W. H. S. Monck.

That while there is a rough agreement between the various determinations of the Sun's motion in space, they differ considerably in details, is known to every one. I propose in this paper to endeavor to investigate the causes of these differences.

First, then, suppose we are seeking to determine the Sun's motion in space by means of stars with large proper motion, we must inquire what are the causes which produce larger proper motion in some stars than in others. These are: (1) Greater vicinity to us; (2) Greater actual velocity; (3) Motion nearly at right angles to the line of sight, so that there is but little foreshortening.

As regards the first of these causes, it is possible that the nearer stars have to a certain extent a common drift in space. If so, the Sun's goal relative to these stars will not be identical with his goal relative to the great mass of the stars. As regards the second and third causes, the stars which we are considering will probably be moving on the average with more than average velocity, both in Right Ascension and in Declination. This will not affect the position of the Sun's goal, but will diminish the effect of the Sun's motion on that of the stars and lead us to underrate the Sun's velocity.

But there is a fourth cause which has the contrary effect, viz: A star is more likely to have large proper motion when the effect of the Sun's motion is additive, than when it is subtractive. Stars with large proper motion may therefore be expected to have on the whole a drift in the opposite direction from the Sun's goal; which would lead us to overrate the velocity of the Sun's motion.

Considering the elements separately, stars with large motion in Right Ascension are likely to possess more than ordinary velocity in Right Ascension, and stars with large motion in Declination are likely to have more than ordinary velocity in Declination. If we treat these two elements impartially, this circumstance will not displace the goal; but this is not always done.

Take the *Cincinnati Catalogue*, for example. The limit adopted for one element is 0″.225 and for the other 0″.150, the latter being the limit in Declination. Professor PORTER adopted this course because errors are more likely to occur in measures of Right Ascension than in those of Declination. But what is the consequence? His stars have on the average greater absolute velocity in Declination than in Right Ascension, and the effect of the Sun's motion will be more sensible in Right Ascension where the average velocity of the stars is less. In consequence of this, the Declination assigned to the Sun's goal will be too small. (But there may be counterbalancing influences to be referred to hereafter.)

Next, suppose we endeavor to determine the Sun's motion by means of stars with small proper motions. Here there is no great danger of a common drift, though it is possible that the great ring of the *Galaxy* (if it be a ring) is revolving. But errors of observation become very material. They are two kinds of errors; casual and systematic.

Casual errors would probably neutralize each other, if we took direction as well as quantity into account, but when we consider quantity only, their tendency is to increase very small motions. Thus, suppose the proper motion of 100 stars in Declination is really insensible, but that there is a probable error of 0″.02 in our observations, their average motion (in quantity) will be ± 0″.02. This increased motion tends to mask the action of the Sun. Indeed, the reason why the real motion of a star is insensible usually being its vast distance, the 100 stars to which I have referred would probably afford hardly any indication of the direction of the Sun's goal. Suppose that they are in a part of the sky where the effect of the Sun's motion is additive and its resolved velocity equal to the average velocity of the stars resolved in the direction of the North Pole, then three-fourths of these insensible motions would probably be plus and only one-fourth minus. But the insensible motions being completely overlaid by casual errors, the pluses and minuses would probably appear to be equal.

Suppose further—which appears to be the case—that these casual errors are greater in Right Ascension than in Declination, the result is, that the effect of the Sun's motion in Right Ascension is more completely overlaid by them than the effect in Declination, with the result that the Sun's goal is placed too near the North Pole. This result seems quite borne out by the computations of Dr. STUMPE and others. STUMPE determined the Sun's goal from four different sets of stars; the proper motion diminishing with each set. He got nearly the same Right Ascension for the Sun's goal, but his Declinations were respectively 42°, 40°.5, 32°.1 and 30°.4. More than one explanation of this result is no doubt possible, but I suspect that the true one is that the effect of the Sun's motion in Right Ascension was becoming more and more masked by errors of observation as the proper motions became smaller, the masking of the effects in Declination being of a less marked character.

But beside casual errors, there are probably systematic errors. Such systematic errors in the case of Right Ascension may arise from a small error, either in the amount of precession, or in the length of the sidereal year. Some of our catalogues seem to me to show unmistakable traces of such systematic errors. Thus, in Mr. STONE'S Catalogue of Southern Stars, I find 205 stars with diminishing Right Ascension against 99 whose Right Ascension is increasing. But when I confine my attention to the stars whose annual motion in Right Ascension amounts to one-fiftieth of a second (in time), this preponderance disappears. It seems clear that there is some small systematic error which gives the stars in this catalogue a small apparent motion in diminishing Right Ascension. These systematic errors would, of course, more effectually mask the effect of the Sun's motion, and if they affected the Right Ascension of the stars only would lead us to assign too high a Declination to the Sun's goal.

When the stars are selected for their magnitudes, not their proper motions, the procedure is liable to other objections. Two causes, besides nearness, affect the magnitude of a star: its intrinsic brightness and its mass or extent of surface. It is therefore natural to conclude that stars of the first magnitude have on the average greater intrinsic brightness and larger masses than those of the second magnitude, and that those of the second magnitude have a similar advantage over those of the third, and so on *ad infinitum*, though the relative preponderance will decrease at every stage and ultimately become insensible. The assumption, therefore, that the average distance of stars varies in the manner indicated by their magnitudes is quite untenable; and, moreover, the stars which are classed together as of the first magnitude—beginning with *Sirius* and ending with *Fomalhaut* or *Pollux*—really cover a range of at least two and one-half magnitudes. They thus differ on the average by more than one magnitude from the stars usually classed as of the second magnitude.

Further, even among bright stars, some have extremely small proper motions, and the uncertainties attaching to a computation resting upon small proper motions have been already pointed out. There is no doubt that the average proper motion of the stars diminishes with their magnitudes to a much smaller extent than would be the case if magnitude could be relied on as an index to average distance, and the average rate of motion was the same at all distances from us. This fact seems to have led Miss CLERKE to conclude that the more distant stars move more rapidly in space, or—which is putting the same fact into a different shape—that the nearer stars have a common drift with the Sun.

But a more probable explanation is, I think: (1) That for reasons already stated, magnitude cannot be relied on as an index to average distance, especially among the brighter stars; and (2) That errors of observation tend to increase small motions and thus to represent the decrease of average proper motion with magnitude as less than it really is. To which I may add that faint stars are often inserted in our catalogues simply on account of their large proper motions. The average proper motion of these stars will, of course, be largely in excess of that of the magnitude to which they belong.

To ascertain the average motion of stars of any given magnitude, we should examine *all* the stars of that magnitude, or at all events make an impartial selection of them. Finally, it is not impossible that there is an absorption of light in transmission through the ether. If so, faint stars are on the average nearer to us than they would be on the hypothesis of perfect transparency, and then average proper motions will be larger than we should expect on that hypothesis.

On the whole, stars with large or at least moderately large proper motion seem to afford the best resource. But I would suggest the desirableness of correcting them roughly for the Sun's motion before using them for a more accurate determination.

Thus, suppose we intend using all known stars whose proper motions exceed half a second in our determinations. Having made out a list of such stars, we should either make a rough estimate of the effect of the Sun's motion or adopt some previous determination of it, and strike out of our list of stars all those whose proper motions are under half a second when thus corrected. Then examine the stars whose proper motion is over, say one-third of a second, in a direction more or less opposed to that of the Sun; let us see how many of these will be increased to half a second when corrected for the Sun's motion. This will give us at all events a better list than we started with, and if greater accuracy is desired, we may, after determining the Sun's motion, correct the list a second time and then redetermine the Sun's motion. For these corrections we should of course know, approximately, the ratio between the Sun's velocity and the average velocities of the stars with which we are dealing.

In the case of stars with large proper motion, for a reason already mentioned, which seems confirmed by the catalogues which I have examined, the Sun's velocity is probably less than the average velocity of the stars in question. Three-fourths of the average would probably be a good supposition to start with, and assuming say $280° + 35°$ for the Sun's goal, the corrected list would no doubt be an improvement on the original one. Not, of course, that the corrected figures should be used in the computation. The object would be only to obtain a better list of stars—a list of stars whose real proper motion exceeds half a second, instead of a list of stars whose apparent proper motion exceeds that limit. When the list was thus revised, the figures in our present catalogues should be used without change. If by this process we obtained a goal differing materially from $280° + 35°$, with indications that the Sun's velocity was greater or less than we had supposed, the list should be revised a second time, using our new results for the purpose of revision. What we want to procure is a table of the *apparent* proper motions of all stars whose *real* proper motion amounts to half a second or upwards in the year.

The method of ascertaining the Sun's motion by spectroscopic observations of the velocities of stars in the line of sight, is as yet in its infancy. But it will probably be a long time before we can depend on the accuracy of very small motions in the line of sight, and larger motions are liable to be disturbed by the vicinity of dark satellites or companions. It may be also that the spectral lines are liable to be displaced by other causes than motion in the line of sight. The spectrum of the *Nova* in *Auriga* is rather startling, if such velocity is the only admissible explanation of it. The velocity of a double star in the line of sight will also vary with the part of its orbit which it is describing, and a larger proportion of the stars are probably binary than we are as yet aware of.

There is thus much to mask the Sun's motion in the phenomena of the stellar spectra, and though VOGEL'S 51 stars may not be very well selected for ascertaining the Sun's goal, I believe their proper motions would afford a closer approximation to its true position than is afforded by their spectroscopic velocities. The computation would be worth making in order to see whether the cause of the variance lay in the method employed or in the selection of the stars.

THE TRANSIT OF *MERCURY*, NOVEMBER 10, 1894, AT WILMINGTON, N. C.

By E. S. MARTIN.

[Abstract.]

The sky, on the 10th, was cloudless. At ingress the Sun's limb was remarkably steady and sharply defined. I was enabled, therefore, to obtain a good observation of the transit from beginning to end. I used my 5-inch CLARK refractor with power of 105.

The first and second contacts were well seen, the limbs of the Sun and planet being sharply defined. I detected no appearance of "black drop" or elongation of the planet at either interior contact, nor did I see the body of the planet, or any light around it, at first contact, on the part exterior to the Sun. But, after second contact and during the entire transit, the planet was surrounded by a halo or corona of a dim gray color which, in contrast with the light of the body of the Sun, had a ghastly white appearance. The estimated width of the halo was about one-third or one-half the diameter of the planet. The body of the planet was intensely black (sometimes blue-black) and exquisitely defined.

I did not see the spot of light on the disc of *Mercury* observed by some at other transits, though some friends (without any knowledge of such a phenomenon) noticed such an appearance, although I could not see it, even when my attention was called to it.

The third and fourth contacts (owing to the agitation of the Sun's limb) were not so easily seen as the first and second.

The times were taken from an excellent Elgin watch, which I compared with the noon signal from the Naval Observatory, and are as follows:

1st Contact*	10^h	57^m	15^s	A. M.	E. S. T.
2d	10	59	08		
3d	4	11	02	P. M.	
4th	4	12	55		

WILMINGTON, N. C., December 10, 1894.

AN INTERESTING TRANSIT OF *JUPITER'S* THIRD SATELLITE.

By E. S. MARTIN.

A transit of *Jupiter's* third satellite, observed the night of December 27, was peculiar in some respects, though I have observed "dark transits" of this satellite before. The satellite and its shadow were on the planet when observation began, at 6^h 45^m, Eastern Standard time. The shadow was intensely black, round and well defined. The satellite, on the contrary, appeared of a dusky hue, its shape a long, irregular ellipse, the longer axis parallel to *Jupiter's* belts, and about one-fourth the apparent size of the shadow. I would have taken it for a spot on a belt, except for its motion. It preserved this shape, color and size, at least until $8^h\ 0^m$, when I was unavoidably called away. The instrument was a 5-inch CLARK refractor, power 200; seeing very good.

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* **Comparing my times of first and second contact with those obtained at neighboring observatories, I am inclined to think my watch must have been fast about 16s. The times of third and fourth contacts seem about right.**

WILMINGTON, N. C., 1894, December 28.

(EIGHTEENTH) AWARD OF THE DONOHOE COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to Mr. EDWARD D. SWIFT, LOWE Observatory, California, for his discovery of an unexpected comet on November 20, 1894.

The Committee on the Comet-Medal,

EDWARD S. HOLDEN,
J. M. SCHAEBERLE,
CHAS. BURCKHALTER.

1895, January 20.

THE IRREGULAR WANING OF THE SOUTH POLAR CAP OF *MARS*.

By W. W. CAMPBELL.

Every observer of *Mars* is well acquainted with the fact that the polar caps in waning do not preserve an exactly circular outline, and are not of equal intensity in all parts. The edges of the caps are sometimes exceedingly irregular, owing both to dark indentations and bright projections. Portions of the caps even become entirely detached, and remain as isolated bright points for several weeks. Moreover, dark regions and excessively bright regions within the caps are common facts of observation. It is certain that the melting of the caps is affected by local conditions; and it is very important to know whether the local conditions at any point are such as to retard or to accelerate the melting.

I have carefully examined the most important recent drawings of the south polar cap, with reference to answering the following questions :

First—Do the excessively bright regions within the cap, the bright projection on the edge of the cap, and the isolated bright points just outside the edge—do these lie at the same places at successive oppositions?

Second—Do they cover light or dark areas on the planet?

Up to 1892 there are very few published drawings of the south polar cap which record these features. SCHIAPARELLI'S maps show several prominent projections from the north polar cap, but none from the south polar cap. Probably many such were noted by him, but his individual sketches are not accessible. His maps and a few of his individual sketches show the south polar cap as essentially triangular in shape.

Mr. N. E. GREEN'S 1877 observations show the polar cap with a very irregular border, but with no striking projections. Isolated bright points are shown in Long. 267°, 282°, 293°, and Lat. — 73°. GREEN named them MITCHEL Mountains, in honor of their discovery in 1845 by MITCHEL of Cincinnati.

Professor YOUNG'S drawing of July 25, 1892, shows an isolated bright point at Long. 210°, Lat. — 65°.

Professor SCHAEBERLE'S drawings of August 24, 27 and 29, 1892, show a long isolated region at the edge on the polar cap, in Long. 310°, Lat. — 75°. His August 7 and 8 drawings show a large projection from the cap at Long. 150°, Lat. — 61°. There was a small projection at Long. 50°, Lat. — 65°, on August 20.

Professor KEELER noted a small projection at Long. 320°, Lat. — 71°, on August 17, 22, 29.

Dr. BARNARD'S drawing of August 21 shows a prominent projection at Long. 320°, Lat. — 69°.

Professor HUSSEY observed a small projection at Long. 335°, Lat. — 65°, on July 23; another small projection at Long. 40°, Lat. — 62°, on August 20; and a large projection at Long. 155°, Lat. — 60°, on August 5, 7, 9, 14.

Mr. CAMPBELL, whose observations extended from July 13 to August 17 and parts of two subsequent evenings, observed a very bright region just inside the polar cap at Long. 330°, Lat. — 65°, on July 17, 18, 19, 20, 26, 27. A similar spot was observed at Long. 35°, Lat. — 65°, on July 17, 18, 19, 20. A very bright spot, partly inside and partly outside the edge of the cap, was observed at Long. 155°, Lat. — 63°, on August 7, 8, 9. On August 27 a large elongated bright region, nearly detached from the polar cap, was observed at Long. 325°, Lat. — 75°.

Very few of the 1894 observations have been published, so I shall use only my own. On June 20, 1894, there was a very bright spot on the edge of the polar cap at Long. 150°, Lat. — 66°. On June 26 and 28 there was a very bright spot, partly inside and partly outside the cap, at Long. 40°, Lat. — 70°. On July 10 there was a large, very bright region on the edge of the polar cap, and projecting somewhat beyond the edge, in Long. 320°, Lat. — 71°. At the next presentation of that portion of the planet, August 3, the bright area just mentioned was detached from the main body of the cap. It was growing smaller and smaller on August 7, 8, 14, 15, until it passed out of view on the further side of the planet. When this region was again turned toward the Earth I did not see the bright spot.

Collecting the observations of 1892 and 1894, we find that the observed phenomena were confined to four regions on the planet. They were approximately the following :

Long. 40°	Lat. — 66°
155	— 62
210	— 60
325	— 70

The three isolated points observed by Mr. Green, in 1877, at Long. 267°, 282°, 293°, Lat. — 73°, do not coincide with any of the above regions. Mr. Green's beautiful drawings show the center of the bright cap as coincident with the pole of the planet. The observations by Bessel, Hall, Schiaparelli, and many others, have shown that the center of the polar cap is near Long. 30°, Lat. — 84°. If on Mr. Green's drawings we draw the meridians from the true pole instead of from the center of the cap, the longitudes of the three white spots will be increased each by 15° or 20°. They would therefore seem to lie very near the bright spot observed in 1892–94 at Long. 325°.

Let us compare the bright regions observed at the last two oppositions with Schiaparelli's map of the planet. In the vicinity of the south pole he has only four bright regions, the first three of which he has colored orange, like the ordinary bright parts of the planet, and the fourth he has colored white, like the polar cap. The positions of the four regions are :

Argyre II	Long. 48°	to 70°	Lat. — 64°	to — 72°
Thyle I	140	186	— 55	— 71
Thyle II	194	243	— 56	— 73
Novissima Thyle	315	332	— 68	— 75

A comparison of the two tables will show that the bright spots and projections observed in 1892–94 were located on SCHIAPARELLI'S four bright regions. On those bright regions, or at least on parts of them, the waning of the polar cap is most retarded. On the Earth we are accustomed to see the snow linger longest in the mountainous regions. If we are permitted to reason from analogy—which is by no means certain—the conclusion to be drawn is that SCHIAPARELLI'S four bright regions, at least in part, are elevated or mountainous.

PLANETARY PHENOMENA FOR APRIL, 1895.

BY PROFESSOR MALCOLM MCNEILL.

APRIL.

Mercury passed its greatest west elongation late in March and is still a morning star at the beginning of April, rising a little less than an hour before sunrise; so that it is barely possible that it may be seen if the atmospheric conditions are very favorable. It draws nearer to the Sun during the month, and on April 30 does not rise until a few minutes after sunrise, although it does not reach conjunction until May 4.

Venus is an evening star and is in good position for observation. It remains above the horizon about three hours after sunset at the end of the month. It is gradually increasing its apparent distance from the Sun and will continue to do so until July, when it reaches greatest east elongation. Its real distance from the Sun in miles diminishes slightly throughout the month and it passes perihelion on April 30.

Mars is still in the western sky in the evening, but sets earlier than before—at $11^h\ 22^m$ on April 30. It is moving rapidly eastward among the stars through the eastern part of *Taurus* and western part of *Gemini.* On April 6 it passes about 4° south of the 2d magnitude star *Beta Tauri.* Its actual distance from the Earth is increasing and on April 30 it is distant from us about twice the mean distance of the Earth from the Sun. Its brightness is also diminishing, but it is still bright as compared with an ordinary star.

Jupiter is in the same quarter of the heavens as *Mars*, and the two planets are in conjunction on the evening of April 25, *Mars* passing about three diameters of the Moon north of *Jupiter.* At the beginning of the month, *Jupiter* sets nearly an hour before *Mars.* It is, like *Mars*, moving eastward among the stars, but at a rate only one-fourth as great.

Saturn rises at a little after 8^h on April 1, and before sunset on April 30; it is in opposition on the morning of April 24. It is, therefore, in good position for observation in the southeastern sky, late in the evening. It is retrograding (moving westward) in the constellation *Virgo*, about 15° east of *Spica*, the brightest star of the constellation. The ratio of minor to major axis of the rings is about 5 to 17. This ratio diminishes very slightly for the next two or three months, and then begins to increase again. On the whole there will be an increase of the minor axis relative to the major for several years to come, but there are annual diminutions of small amount owing to change of the position of the Earth in relation to the plane of the rings, due to the annual motion of the Earth around the Sun.

Uranus follows about an hour after *Saturn* and about 7° south. It is about 8° south of the 3d magnitude star *Beta Libræ.*

Neptune is in the constellation *Taurus*, too near the Sun and too faint to be easily seen.

EXPLANATION OF THE TABLES.

The phases of the Moon are given in Pacific Standard time. In the tables for Sun and planets, the second and third columns give the Right Ascension and Declination for Greenwich noon. The fifth column gives the local mean time for transit over the Greenwich meridian. To find the local mean time of transit for any other meridian, the time given in the table must be corrected by adding or subtracting the change per day, multiplied by the fraction whose numerator is the longitude from Greenwich in hours, and whose denominator is 24. This correction is seldom much more than 1^m. To find the standard time for the phenomenon, correct the local mean time by *adding* the difference between standard and local time if the place is west of the standard meridian, and *subtracting* if east. The same rules apply to the fourth and sixth columns, which give the local mean times of rising and setting for the meridian of Greenwich. They are roughly computed for Lat. 40°, with the noon Declination and time of meridian transit, and are intended as only a rough guide. They may be in error by a minute or two for the given latitude, and for latitudes differing much from 40° they may be several minutes out.

The eclipses of *Jupiter's* satellites are those which are visible from some part of the United States. A number of those given take place before sunset on the Pacific Coast, but may be seen in the eastern part of the country. All of them take place off the right-hand limb of the planet and below the belts, as seen in an inverting telescope, and those of the outer satellite "IV," at a considerable distance from the planet. *D* denotes disappearance, *R*, reappearance.

PHASES OF THE MOON, P. S. T.

		H. M.
First Quarter,	April 2,	1 28 P. M.
Full Moon,	April 9,	5 43 A. M.
Last Quarter,	April 16,	3 22 P. M.
New Moon,	April 24,	5 11 P. M.

THE SUN.

1895.	R. A. H. M.	Declination. ° '	Rises. H. M.	Transits. H. M.	Sets. H. M.
Apr. 1.	0 42	+ 4 33	5 46 A.M.	12 4 P.M.	6 22 P.M.
11.	1 19	+ 8 20	5 30	12 1	6 32
21.	1 56	+ 11 52	5 15	11 59 A.M.	6 43
May 1.	2 34	+ 15 5	5 2	11 57	6 52
			MERCURY.		
Apr. 1.	23 9	− 7 53	4 52 A.M.	10 29 A.M.	4 26 P.M.
11.	0 3	− 2 28	4 51	10 45	4 39
21.	1 5	+ 4 45	4 50	11 8	5 26
May 1.	2 18	+ 13 7	4 54	11 42	6 30
			VENUS.		
Apr. 1.	2 31	+ 15 7	6 57 A.M.	1 53 P.M.	8 49 P.M.
11.	3 19	+ 19 4	6 51	2 2	9 13
21.	4 9	+ 22 13	6 48	2 12	9 36
May 1.	5 0	+ 24 22	6 50	2 23	9 56

MARS.

1895.	R. A. H. M.	Declination. ° ′	Rises. H. M.	Transits. H. M.	Sets. H. M.
Apr. 1.	5 5	+24 25	8 54 A.M.	4 27 P.M.	11 59 P.M.
11.	5 32	+24 49	8 40	4 14	11 48
21.	5 58	+24 57	8 26	4 1	11 36
May 1.	6 25	+24 49	8 14	3 48	11 22

JUPITER.

Apr. 1.	5 55	+23 27	9 46 A.M.	5 16 P.M.	12 46 A.M.
11.	6 0	+23 29	9 13	4 42	12 11
21.	6 7	+23 29	8 40	4 9	11 38 P.M.
May 1.	6 14	+23 28	8 8	3 37	11 6

SATURN.

Apr. 1.	14 17	−10 51	8 14 P.M.	1 40 A.M.	7 6 A.M.
11.	14 14	−10 36	7 31	12 58	6 25
21.	14 11	−10 21	6 48	12 16	5 44
May 1.	14 8	−10 6	6 2	11 30 P.M.	4 58

URANUS.

Apr. 1.	15 8	−17 14	9 29 P.M.	2 31 A.M.	7 33 A.M.
11.	15 7	−17 9	8 48	1 50	6 52
21.	15 5	−17 2	8 7	1 10	6 13
May 1.	15 3	−16 56	7 26	12 29	5 32

NEPTUNE.

Apr. 1.	4 49	+20 59	8 51 A.M.	4 10 P.M.	11 29 P.M.
11.	4 50	+21 2	8 12	3 31	10 50
21.	4 51	+21 4	7 34	2 53	10 12
May 1.	4 52	+21 6	6 54	2 15	9 34

ECLIPSES OF *JUPITER'S* SATELLITES, P. S. T.

		H. M.			H. M.
I R.	Apr. 5,	7 40 P.M.	III D.	Apr. 17,	5 7 P.M.
II R.	6,	7 53	III R.	17,	8 7
III R.	10,	4 6	I R.	21,	6 0
I R.	12,	9 36	III D.	24,	9 7
II R.	13,	10 29	IV D.	27,	5 30
I R.	14,	4 5	IV R.	27,	8 7

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ASTOR, LENOX AND
TILDEN FOUNDATIONS.

THE LOWE OBSERVATORY.

By C. D. Perrine.

The members of the Society will doubtless be interested to know something of this observatory, which has just been established in the Sierra Madre mountains, in the southern part of the State. The present location of the observatory is near Echo Mountain House, at the head of the cable incline of the Mount Lowe railway. Echo Mountain House is the present terminus of this mountain railway system, leading from Pasadena and eventually intending to reach the summit of the Sierra Madre at an altitude of about 6,000 feet. The Mount Lowe railway, with its system of hotels and pleasure resorts, is one of the enterprises inaugurated by Professor T. S. C. Lowe, a wealthy resident of Pasadena, who has gained distinction by his efforts in aëronautics, in the making of artificial ice, and in "water-gas" processes.

Altadena Junction, on the line of the Los Angeles Terminal Railway is the starting point of the mountain railway, which, as a trolley line for two and a half miles, ends at Rubio Cañon at an altitude of 2,200 feet; here the cable incline commences, and, in a climb of 3,000 feet on a heavy grade, attains the altitude of Echo Mountain—3,500 feet. Here and at Rubio Cañon are located hotels for the accommodation of the tourist.

From the present terminus an electric road is in process of construction to the summit of Mount Lowe, 2,500 feet higher and 7 miles distant. At present this part of the journey is made over a trail mule-back.

The observatory is at present situated on a slope of the mountain, about a quarter of a mile from Echo Mountain House, and consists of three rooms besides the dome. Near by is a photographic dark-room for use in connection with the observatory; the roof of this dark-room being utilized for the 4½-inch comet-seeker. The main instrument of the observatory at present is the 16-inch Clark refractor, belonging to Dr. Lewis Swift, and was brought by him from Rochester, New York.

Dr. Swift, who is in charge of the Lowe Observatory, was formerly of the Warner Observatory. His son Edward is his able assistant, and has already distinguished himself by his discovery of Comet *e*, on November 20. This discovery is of more than ordinary interest, as it may be that this comet is identical with DE VICO's lost comet of 1844. In a recent issue of the *Mount Lowe Echo* he announces the discovery of another comet in *Ursa Major*, on December 16, but before it could be identified the Moon arose and obliterated it; the next two nights were cloudy, and on the following night a search failed to find it.

Upon the completion of the railway to the summit, the observatory is to be permanently located there, and it is the intention to add several instruments to the equipment. The most important addition is to be a 3-foot reflector, which is to be used chiefly for photographic work.

Dr. SWIFT is much pleased with the great number of clear nights which the Sierra Madre afford. In a recent letter he says that, from April 20 to December 1, the cloudy nights have scarcely averaged three per month.

Visitors are permitted to look through the telescope every night, we understand. Besides a post and telegraph office, Echo Mountain has its newspaper—the *Mount Lowe Echo*, Professor G. WHARTON JAMES, editor—to whom we are indebted for the illustrations of the observatory which are here presented.

The large search light from the Midwinter Fair has been purchased and mounted at Echo Mountain.

THE PROGRESS OF METEOROLOGY IN THE UNITED STATES.

BY A. L. COLTON.

[ELEMENTARY METEOROLOGY. By W. M. DAVIS. Boston: GINN & Company. 1894.]

It is but very recently that meteorology, the youngest of the applied sciences, has gained any importance as a distinct subject to be taught in schools and colleges, although there is apparently no older topic than the weather. The long list of ridiculous "signs," upon which the weather-wise have based their predictions, still has a strong hold on the popular mind. A prime reason for the slow development of this science is the instability of the elements involved, and the corresponding difficulty of performing upon them definite experiments.

Almost from the invention of the barometer, two hundred and fifty years ago, occasional suggestions have been made by scientific men, looking to the systematic study of weather phenomena. In a few cities of the eastern states observations of temperature and precipitation were undertaken nearly a hundred and fifty years ago, and were continued with more or less regularity. During the first half of the present century a few papers were published on the movements of storms, notably by REDFIELD and ESPY, and though weather predictions, in the modern sense of the term, were not practicable, efforts were made for the establishment of a systematic weather service under governmental supervision. Through the personal efforts of a few officials in various branches of the Government, observations were made and to some extent digested. The Smithsonian Institution was especially efficient in this work, and gradually absorbed the observations carried on under other auspices, so that in 1870 it controlled nearly all the meteorological records of the country.

The invention of the telegraph rendered possible the forecasting of storms from simultaneous observations made in different places and communicated to one central station. Lieutenant M. F. MAURY was the first to recognize the great field of work thus opening, and during the "fifties" labored for the establishment by Congress of a central office from which reports might be telegraphed over the country, warning farmers of the approach of storms and frosts. Before he could succeed, however, the plan was lost from sight in the excitement of the civil war. In 1856 the Smithsonian Institution received simultaneous reports by wire, and for a time maintained a daily weather-map. At about the same time WILLIAM FERREL, a mathematician of great originality, began his studies on the effects of the Earth's rotation upon atmospheric currents; these studies, continued to later years, resulted in the first rational theory of the general circulation of the atmosphere.

In 1869 Professor CLEVELAND ABBE, then director of the observatory at Cincinnati, with the aid of the Chamber of Commerce of that city, issued the *Weather Bulletin of the Cincinnati Observatory*, containing daily weather forecasts, and continued this publication until January, 1871, when he was called to Washington to assist in the forecasting work of the Signal Corps.

Shortly before this time, by the exertions of several individuals, largely civilians, but including General MYER (Chief Signal Officer), Congress passed a resolution creating the Meteorological Bureau of the Signal Corps. This service went into effect November 1, 1870, and for more than twenty years maintained with excellent results a system of weather predictions for the United States. The work at length far overshadowed the original duties of the Corps, which related only to military signaling in the army. Toward the end of this period strong dissatisfaction had arisen both within and without the service, and efforts to have the meteorological work transferred from a military to a civil basis were at length successful. In 1891 the Weather Bureau of the Department of Agriculture was organized, and, upon taking charge of the meteorological service of its predecessor, improved it in various ways, with especial reference to the needs of the agricultural class.

Such is a brief summary of the history of meteorology in the United States. This history seems to be little understood, even yet, for individuals, and even newspapers, when referring to the weather predictions, often speak vaguely of the "Signal Service," and the "Signal Service Bureau," with as little regard for accuracy as those who use the word "cyclone" where "tornado" is meant.

Before the Signal Corps began its work of weather forecasting, the study of meteorology was confined to comparatively few persons, and chiefly to scientific men of some prominence. With the growth of the Signal Service more extensive instruction in meteorology became a necessity, and this was largely supplied to the new members of the Corps at Fort Meyer, Va. A few colleges gradually included courses in this science; but, as a whole, the work was feebly carried on. The instruction afforded by the Government, and lucrative positions as observers, were to be had only by joining the army for a term of years—something distasteful to the average civilian. With the establishment of the Weather Bureau, the observers who remained in the weather service lost their military standing, but were soon placed under civil service protection, and the force somewhat enlarged. At the same time a campaign of popular education was inaugurated, both to lead the public to a higher appreciation of the benefits of the weather service and coöperation in its work, and to advance the study of the science of meteorology in schools and colleges. Competent officials of the Bureau were encouraged to promote these objects by the delivery of public lectures and in other ways, and especially by furnishing schools with the daily weather-maps and leading the students to a knowledge of the more elementary laws of storms. This policy was justified by the hearty welcome with which the public received the newly-established Bureau, and the results have been highly satisfactory.

Under the military *régime* comparatively few college graduates sought positions in the weather service, though many found places in the State and national geological surveys, and in other public scientific work. Under the present system, the force of observers and other trained employees in the Weather Bureau must be recruited from the educated young men of the country, by competitive civil service examination. A new field has thus been opened to suitably prepared persons who have tastes in this direction.

Hitherto, no suitable American text-book of meteorology, sufficiently elementary and at the same time comprehensive and up to date, has been available for the use of students in high-schools and colleges, and for the constantly increasing class of general readers who are seeking the information that such a book might afford. LOOMIS' "Meteorology," once very useful in its way, is now far behind the present conditions and requirements of the science. FERREL'S works are highly mathematical, and even his "Popular Treatise on the Winds," a very excellent book, intended for more general reading, is too technical for the purpose mentioned. A few modern works of a popular nature have been published, but mostly specific in character and hardly filling the want of a general text-book. To these and to magazine articles the public has had to look for instruction. In schools the text-books of physics and physical geography afford some scattering information, and in colleges instruction in meteorology is largely given by means of lectures, and also, latterly, by laboratory work.

The work named at the head of this article, written by the professor of physical geography in HARVARD University, is our first text-book designed to fill the needs just mentioned, and as such marks an epoch in the progress of meteorological education. In the space of about 350 octavo pages Professor DAVIS has given, in very attractive form, a compendium of the science of meteorology as it exists to-day, omitting the mathematical processes only suitable for advanced students; he gives, however, many of their results. Upon reading the book and noting the sequence of the topics and the logical manner of their development, one readily sees that this is the work of an experienced teacher.

The titles of the fourteen chapters will convey an idea of the scope of the book: The general relations of the atmosphere; extent and arrangement of the atmosphere about the Earth; the control of atmospheric temperatures by the Sun; the colors of the sky; the measurement and distribution of atmospheric temperatures; the pressure and circulation of the atmosphere; a general classification of the winds; the moisture of the atmosphere; dew, frost, and clouds; cyclonic storms and winds; local storms; the causes and distribution of rainfall; weather; climate.

The author states that the greatest share of whatever is valuable in this book comes from his having studied and followed the work of FERREL; and the latter's theories of the motions of the atmosphere are simply and non-mathematically stated, and given a position of fundamental importance. It is expected that students who follow this book will have had preparation to the extent of the usual high-school course in physics. The fundamental principles needed are so clearly stated as scarcely to make even this preparation an absolute essential, though the scientific training and power of attention to be gained from such a course will be highly useful to the reader. The preface gives a list of books suitable for collateral reading, and some advice as to methods of teaching; suggestions are also given for original work.

Considerations of space will hardly permit extended notice of particular portions of the book. The chapter treating of the colors of the sky, the dust of the atmosphere, and various optical phenomena of the atmosphere, seems especially interesting. In the chapter on the distribution of atmospheric temperatures the influence of the ocean currents is dwelt upon at considerable length; the omission of a chart of these currents seems to be a little unfortunate. Of cloud observations the author says: "If the observer wishes to learn something of atmospheric processes for himself, he should give at least as much time to cloud observations as to all the other records together." Storms which cannot be clearly attributed to periodic changes of temperature are classified as cyclones, thunder-storms and tornadoes. Some attention is given to atmospheric electricity. The illustrations are numerous and well-executed. The principal meteorological instruments are described, with cuts, and in many cases information is given as to cost.

On page 96 the height of Mount Hamilton is given as 4,400 feet; the LICK Observatory, where meteorological observations are taken, is slightly more than 4,200 feet above sea-level. Other accidental errors have not been noticed; absolute freedom from such is hardly to be expected, especially in a first edition.

It may be mentioned, in conclusion, that the mechanical execution of the book is excellent in every way.

THE CLIMATE OF *MARS*.

BY MARSDEN MANSON.

The fact that *Mars* presents phenomena which indicate milder polar climates than exist upon the Earth seems to puzzle many students of astronomy. Instead of endeavoring to account for these phenomena by logical deductions from admitted facts and known laws, some seem to find pleasure in exercising their ingenuity by ascribing remotely possible conditions, and then in accounting for these conditions by processes of argument which strain the faith of their co-workers beyond its limit of elasticity.

The writer will endeavor to show that the climatic conditions, generally admitted to exist upon *Mars*, can be explained without resorting to suppositions and hypotheses bordering near the limits of common sense. The arguments will be simple and fundamental. Until these simple explanations shall be shown to rest upon incorrect premises, or that wrong conclusions have been drawn, the scientific imagination should be restrained within reasonable bounds.

The mean distance of *Mars* from the Sun is about one and one-half times the mean distance of the Earth; and its volume is about one-seventh that of the Earth. Unlike the rest of the planets, its own and other satellites, *Mars* reflects a rich ruddy light—an important factor in interpreting climatic conditions. Upon equal areas the heat and light received by *Mars* is less than one-half that received by the Earth; it by no means follows that its climates are proportionately colder, for the actual amount of heat a planet receives is not the only prime factor in its surface temperatures. There are other factors which bear an important part, and arguments omitting these are fallacious. It is the omission of these factors which has rendered the climatic conditions prevalent upon *Mars* difficult of interpretation, and has caused some astronomers to doubt the prevalence of milder climates upon *Mars* than upon the Earth. Others have considered the propriety of substituting some other substance than water to account for the formation and disappearance of the polar snow-caps.*

As either pole of *Mars* emerges from its winter, comparatively white spots are observed to encircle it. These spots generally reach down to Lat. 84° or 82°, or 6° or 8° from the pole, although the snow sometimes extends down to latitude 60° to 55°, or through an arc of from 60° to 70°; they disappear in whole or in part as the pole is towards the Sun in the following summer. The disappearance on the edges is rapid, but the true polar spots are persistent for months. These phenomena admit of the simple explanation usually rendered, namely, that these spots are polar snow-caps which form and melt off with the seasons; but the task of explaining how a planet receiving less than half the heat and light which the Earth receives could enjoy so mild a winter and so warm a summer at polar latitudes has been heretofore considered difficult.

Dr. BATES† argues that these polar spots may be fields of carbon di-oxide (CO_2), and his theory is accredited with having much in its favor by Professor CAMPBELL‡ of the LICK Astronomical Department of the University of California. Neither authority accounts for what would have become of any water which may have existed upon *Mars*, and which would have been condensed before the carbon di-oxide; nor why, upon the evaporation of the carbon di-oxide, we do not see the equally white snow and ice which must have been frozen and precipitated before the planet reached the extremely low temperature at which carbon di-oxide congeals. Before this remarkable interpretation can be discussed, it must be shown that water never did exist upon *Mars*, for it would have been congealed first, and would have shrouded the planet in white, upon which surface the condensation and evaporation of the equally white carbon di-oxide could not be observed. The same is true for any other substitute having a freezing point between that of water and — 109° Fahr.— the freezing point of carbon di-oxide. Whatever may be the freezing point of the substance causing the polar snow-caps, this substance has the highest, not the lowest freezing point of the congealable constituents of the atmosphere of *Mars*, for upon its evaporation we observe the general surface of the planet.

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* *Publications* A. S. P., Vol. VI., No. 38, page 300.

† *Publications* A. S. P., Vol. VI., pages 300-302.

‡ *Ib.*, page 280.

THE OMITTED FACTORS.

In the life of a planet there is a period between the final exhaustion of its own available heat and the reign of solar heat, during which period glacial conditions are extensive and permanent for a great length of time. This period the Earth has manifestly passed through, as continental glaciers once existing have disappeared, and their feeble remnants are yet retreating upwards and polewards in tropical, temperate, and even polar latitudes. This retreat is very slow, but is distinctly noticeable wherever glaciers yet rest. It therefore follows that since the period when these glaciers were most extensive, there has been a general rise in temperature. As this rise is yet in progress, it must be accounted for by laws now active.

It has been previously stated that the actual amount of heat received by a planet was not the sole factor influencing its surface temperatures; other factors are equally and probably more important. Their existence and influence are made apparent in the general rise in terrestrial temperatures since the culmination of the period of great glacial extension over now temperate and tropical areas. One of these factors or causes is the power of the atmosphere to trap heat. TYNDALL* and BUFF† have shown that by contact with the planetary surface solar light and heat-rays are converted into dark heat-rays, and are trapped; and that this power to trap dark heat-rays is held individually and collectively by the various constituents of the atmosphere. Some gases, and notably the odor of flowers, possess this power to a high degree. Now, when this heat-trapping process is inaugurated upon a planet, it is no longer a heat-losing body, but a heat-gathering body in space; for its rate of receipt of heat is greater than its rate of loss. The process has a moderate limit fixed by the evaporation of water, which evaporation, when excessive, shuts out solar energy by extensive cloud formation.* The mean surface temperatures of the Earth have thus gradually risen from the lower temperatures prevailing during past glacial extension. As the progress of this rise is yet being recorded by the retreat of glaciers in both hemispheres and at all latitudes, and as it was inaugurated at a comparatively remote period in the past, the factor time has entered into the result as a third important cause. Thus the solar climates of a planet are determined by three prime causes, or factors: first, the actual amount of heat and light received; second, the heat-trapping power of its atmosphere — determining the difference between its rate of receipt and rate of loss of heat; third, the time these two factors or causes have been operating.

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* *Proceedings Royal Society*, Vol. XIII, page 160; *Archives des Sciences*, Berne, Vol. V, page 293.

† *Ib.*, Vol. LVII, page 293.

In the application of this reasoning to *Mars* we can fix, in general terms, the comparative value of each cause; the logical result of the combination being that *Mars* must enjoy a milder general climate than the Earth.

As regards the first, the amount of heat and light *Mars* receives is readily calculated to be about 0.43 that received by the Earth.

The existence and operation of the second cause is made manifest by the deficiency of blue rays and the excess of red and orange rays in the solar light *Mars* transmits to us, thus establishing the fact that the Martian atmosphere has the power of abstracting and retaining those rays which are most readily trapped by the atmosphere of the Earth. This deficiency in the rays most readily trapped shows that there is a positive difference between the rates of receipt and loss of solar energy; or in other words that *Mars*, like the Earth, is either a heat-gathering body, and that its surface temperatures are yet gradually rising; or, that its surface temperatures are constant, and the excess of solar energy is used in maintaining these constant conditions, and in work upon the planet's surface.

The third cause—the factor time—is necessarily greater than the corresponding factor in the case of the Earth; for *Mars*, having a mass less than one-ninth that of the Earth, lost his internal heat at an earlier period, and therefore became a heat-gathering body at an earlier period than the Earth.

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* The climate of *Venus* seems to be thus modified.

Thus all three of the prime causes are positive in their effects, irrespective of a constant or slowly decreasing source of heat, and omitting the unknown, but positive and constant factor—stellar heat. It is therefore reasonable to conclude that the phenomena observed are correctly interpreted to mean that *Mars* enjoys a milder general climate than the Earth.*

This reasoning admits of application to any planet of any system, and it is reasonable to infer that similar climatic conditions must in time be established upon any planet having a heat-trapping atmosphere.

San Francisco, Cal., January 27, 1895.

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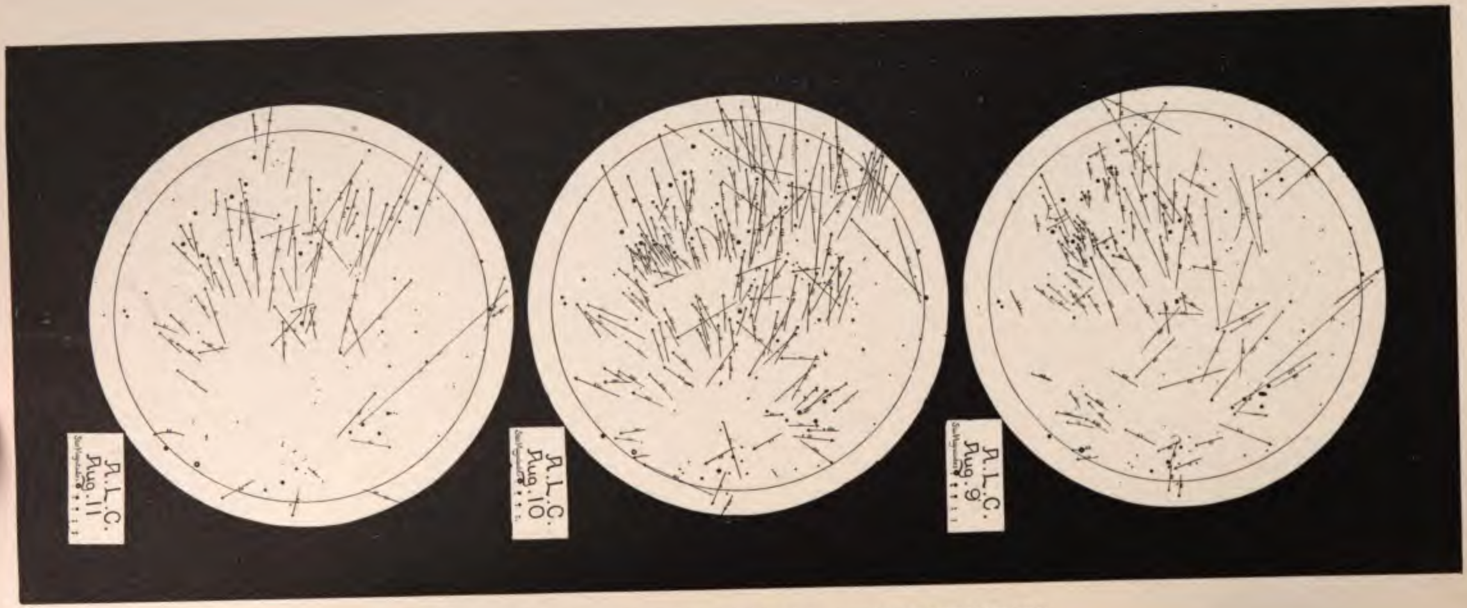
* The supposed Martian Arctic explorer, referred to by Professor Campbell, has a trip corresponding to a summer jaunt through Norway and Sweden. Probably an equally pleasant trip awaits future explorers of our polar regions.



METEOR PATHS OBSERVED AT THE LICK OBSERVATORY.

By A. L. Colton, 1894, August 9, 10, 11.

NOTICES FROM THE LICK OBSERVATORY.

PREPARED BY MEMBERS OF THE STAFF.

AMERICAN ASTRONOMICAL JOURNALS.

We print below the list of editors of a new astrophysical journal whose chief editors are Professor HALE and Dr. KEELER. It is to be published by the University of Chicago, and will continue the astrophysical sections of *Astronomy and Astro-Physics.* The latter journal is a continuation and enlargement of the *Sidereal Messenger*, founded by Professor W. W. PAYNE in 1882. America's astronomical journals have been as follows:

(1) *The Sidereal Messenger*, founded by Professor O. M. MITCHEL in July, 1848. Vol. I (Nos. 1–16) and Vol. II (Nos. 1–12) are all that were printed; or at least all that are contained in the set belonging to the LICK Observatory library.

(2) *The Astronomical Journal* was founded by Dr. B. A. GOULD in November, 1849, and it comprises fourteen volumes: Vol. I (1849–1851) to Vol. XIV (1894) now current. Dr. GOULD and Dr. CHANDLER are the present editors.

(3) *The American Journal of Science*, founded by Professor SILLIMAN in 1818, has always contained valuable articles on astronomy, though its chief use has been to represent the natural sciences, rather than astronomy. Professor H. A. NEWTON has been for many years its astronomical and mathematical editor.

(4) *Astronomical Notices* was founded by Professor F. BRUENNOW in 1858. The LICK Observatory library copy contains Nos. 1–28 (November, 1858, to December, 1861). I believe a few more numbers were printed, but not generally distributed.

(5) *The Sidereal Messenger* was founded by Professor W. W. PAYNE in 1882, and ten volumes were printed, namely Vol. I (1882) to Vol. X (1891). It was succeeded by

(6) *Astronomy and Astro-Physics*, edited by Professors PAYNE and HALE. Three volumes were printed, and they were numbered in continuation of the *Messenger*, Vol. XI (1892), Vol. XII (1893), Vol. XIII (1894). With the completion of Vol. XIII the two preceding journals come to an end.

(7) *The Publications of the Astronomical Society of the Pacific* is not strictly a journal, since it is the organ of a society. It is open, however, to all suitable papers. It is edited by a committee, and six volumes have been printed. Vol. I (1889) to Vol. VI (1894) now current.

(8) *Popular Astronomy* was founded by Professor W. W. PAYNE in 1893, and Vol. II is now current.

(9) *The Astrophysical Journal* begins its publication with Vol. I, No. 1 (ten months a year), in 1895.

The *Astronomical Journal* (2), *The American Journal of Science* (3), The *Publications* A. S. P. (7), *Popular Astronomy* (8), and *The Astrophysical Journal* (9) will undoubtedly continue to be printed. It is also understood that the journal *Science* is again to be reformed and put on a proper footing. Its astronomical editors are to be Professors NEWCOMB and E. C. PICKERING. With these journals available for general astromomy and astronomical physics and with two others (*American Mathematical Journal* and *Annals of Mathematics*—not to speak of the *Bulletin of the New York Mathematical Society*) available for contributions in the department of mathematical astronomy, it seems that Americans can have no cause to complain of lack of facilities for making their work known.*

In a general way the multiplication of scientific journals is to be deprecated; but each one of the foregoing covers a special field and is likely to do useful service. In particular it is certain that the new *Astrophysical Journal*, with its very strong staff of editors, and with the support of a great University, will be a powerful incentive to science. Members of the LICK Observatory staff are on the editorial boards of three of the five astronomical publications. E. S. H.

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* No account of astronomical journals is complete without a mention of *Astronomische Nachrichten*, founded by SCHUMACHER (1821), and continued under the editorship of PETERS and KRUEGER. It is now the organ of the *Astronomische Gesellschaft*, an international society which numbers many Americans in its membership. Under its present management, especially, it is a truly international journal, and welcomes contributions of value from astronomers of any nation.

MOUNT HAMILTON, December 15, 1894.

THE ASTROPHYSICAL JOURNAL. An International Review of Spectroscopy and Astronomical Physics (continuing *Astronomy and Astro-Physics*).

Editors—GEORGE E. HALE, Director of the YERKES Observatory; JAMES E. KEELER, Director of the Allegheny Observatory.

Assistant Editors—J. S. AMES, Johns Hopkins University; W. W. CAMPBELL, LICK Observatory; HENRY CREW, Northwestern University; E. B. FROST, Dartmouth College; F. L. O. WADSWORTH, University of Chicago.

Associate Editors—M. A. CORNU, École Polytechnique, Paris; N. C. DUNÉR, Astronomiska Observatorium, Upsala; WILLIAM HUGGINS, Tulse Hill Observatory, London; P. TACCHINI, R. Observatorio del Collegio Romano, Rome; H. C. VOGEL, Astrophysikalisches Observatorium, Potsdam; C. S. HASTINGS, Yale University; A. A. MICHELSON, University of Chicago; E. C. PICKERING, HARVARD College Observatory; H. A. ROWLAND, Johns Hopkins University; C. A. YOUNG, Princeton University.

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DISCOVERY OF A NEW GAS IN THE EARTH'S ATMOSPHERE.

In *Nature's* account of the meeting of the British Association for the Advancement of Science, held at Oxford, in August, there is a paragraph devoted to a most interesting discovery. It seems that the eminent investigators Lord RAYLEIGH and Professor RAMSAY announced the discovery of a new substance in our atmosphere. Certain experiments made by CAVENDISH seemed to point to the presence in air of some substance other than the gases with which we are familiar. Lord RAYLEIGH and Professor RAMSAY'S attention was recalled to this substance by the fact that the density of nitrogen taken from the air differs about one-half per cent. from the density of nitrogen taken from other sources of that gas. The new and unknown substance was isolated by subjecting nitrogen taken from the air to the action of magnesium. The magnesium absorbed the nitrogen and left a residual gas whose density was nearly 50 per cent. greater than that of nitrogen. The newly discovered substance seems to constitute about 1 per cent., by weight, of the atmosphere. It gives a spectrum consisting of a single line in the blue.

The investigators have not made the details of their work public, but it is announced that they will present them at a meeting of the Royal Society in the near future. W. W. C.

On Photographing the Solar Corona Without an Eclipse.

The importance of obtaining an accurate knowledge of the constitution and physical condition of the solar corona is very great. Our present knowledge on that subject is extremely meagre, and is advancing at an exasperatingly slow rate. We are able to observe the corona only during the moments of total eclipses, and the most persistent eclipse observer cannot expect more than one hour for such observations in his whole lifetime. To remedy this misfortune, many commendable attempts have been made to see and to photograph the corona without the aid of an eclipse. Professor GEO. E. HALE, Director of the YERKES Observatory, has an interesting paper giving the history of these attempts in the October *Astronomy and Astro-Physics.* Unfortunately he had only failures to chronicle. The most recent trials were those made by Professor HALE on Pike's Peak in 1893, and Mount Etna in 1894. In conclusion, he writes: "While it can hardly be said that the results of my various attempts to photograph the corona without an eclipse have been at all encouraging, I have by no means abandoned hope that the method, if fairly tried under good conditions, may yet be successful. In choosing a site great care should be taken. On Pike's Peak the dust was very troublesome. * * * There was much more dust on Etna than on the Peak. * * * A snow-covered peak might offer important advantages in this and other particulars." W. W. C.

PRIZE FOR EXCELLENCE IN COMET OBSERVATIONS.

Early in 1893 *The Astronomical Journal* offered a special prize of $200 to the observer, a resident of the United States, who should make the best series of observations for determining the positions of comets between 1893, March 31, and 1894, September 30. The award has recently been made to Professor J. G. PORTER, of the Observatory of Cincinnati. The judges were Professor ASAPH HALL of Washington, Professor LEWIS BOSS of the DUDLEY Observatory at Albany, and Dr. S. C. CHANDLER of Boston. W. W. C.

THE DISCOVERY OF ASTEROIDS IN 1894.

Twenty-four asteroids were discovered in 1894: twelve by CHARLOIS of Nice, six by WOLF of Heidelberg, two by COURTY of Bordeaux, one by BIGOURDAN of Paris, one by BORRELLY of Marseilles, one by WILSON of Northfield, Minn., and one by ROBERTS of England. The number of asteroids now known is just about four hundred. W. W. C.

THE COMETS DISCOVERED IN 1894.

Five comets were discovered in the year just past.

Comet *a* 1894 was discovered by DENNING at Bristol, England, March 26. It was a faint telescopic comet, moving in an elliptic orbit around the Sun once in about seven years. It is thus a newly discovered member of the solar system.

The most interesting comet of the year was Comet *b*, discovered by GALE, at Sydney, Australia, on April 3. At its brightest it was of the 5th magnitude and therefore easily visible by naked eye. For a few days an extremely faint tail was just visible by telescopic assistance, but a tail of considerable length was shown on the photographs obtained by BARNARD at LICK Observatory, RUSSELL at Sydney, and WOLF of Heidelberg. The comet was moving in a parabolic orbit. The spectrum of this comet, consisting of about twenty-five bright lines, was identical in every respect with that of Comet *b* 1893. Its principal constituents were therefore carbon and cyanogen.

Comet *c* 1894 was TEMPEL'S periodic comet, re-discovered on May 8 by FINLAY, at the Cape of Good Hope.

Comet *d* 1894 was ENCKE'S periodic comet, re-discovered by CERULLI, at Teramo, on November 1.

Comet *e* was discovered by EDWARD SWIFT at Mount Lowe California, on November 20. It was a very faint telescopi comet, and may possibly prove to be DE VICO's periodic comet

W. W. C.

THE PERIODICITY OF THE SUN-SPOTS.

Mr. W. T. LYNN has suggested, in *The Observatory* for 1893, August, and 1894, October, that possibly the periodicity of Sun-spots is due to collisions with meteors moving in an orbit such that their period around the Sun is 11.1 years and the perihelion is very near the Sun's surface, the meteors being more numerous in one part of the orbit than in others. We commented upon Mr. LYNN's interesting suggestion in No. 32 of these *Publications*. We find that identically the same hypothesis is contained in YOUNG's excellent book on "The Sun" (date 1881), page 151. Professor YOUNG attributes the idea to Sir JOHN HERSCHEL, and clearly states its merits and demerits. W. W. C.

ERRATUM IN HUSSEY'S LOGARITHMIC TABLES.

Since a list of the corrections to these tables was printed in the last number of these *Publications*, it may be well to make note of another error, though it is of the character not likely to give trouble to any one using them.

Page 110: The characteristic of Nat. sin . 5° 60′ should be 0, in place of 9. R. H. T.

THE LATITUDE VARIATION AT LICK OBSERVATORY IN 1893 AND 1894.

For the determination of the latitude by meridian circle observations, it has been useful to compute the variation according to the results of CHANDLER'S investigations. His formula, given in the *Astronomical Journal*, Vol. XIV, No. 17, has been used for this purpose, and is as follows:

$$\begin{aligned}\phi - \phi_0 = &- 0''.16 \cos\left[\lambda + (t - 2411790)\, 0^\circ.85\right] \\ &- 0''.11 \cos \lambda \cos \odot + 0''.11 \sin \lambda \sin (\odot - 300^\circ)\end{aligned}$$

The variation has been computed for the first day of each month, from September, 1893, to January, 1895, covering the period during which active work has been done with the meridian circle upon the present series.

It will be evident that this is a period of slight change in the latitude at this point; the total range of variation being barely more than a tenth of a second. The latitude observed will then have but small corrections, smaller than the actual probable error of the determination.

			$\phi - \phi_0$
1893,	September	1	+″.04
	October	1	− .01
	November	1	− .04
	December	1	− .06
1894,	January	1	− .06
	February	1	− .04
	March	1	− .02
	April	1	− .01
	May	1	.00
	June	1	.00
	July	1	− .01
	August	1	− .01
	September	1	− .01
	October	1	.00
	November	1	+ .02
	December	1	+ .04
1895,	January	1	+ .07

There will be available for the latitude discussion, during this period, about 500 observations of the circumpolar stars of the Berlin *Jahrbuch*, distributed between upper and lower culminations; and 700 observations of equatorial stars of the same list.

R. H. T.

CORRECTION TO THE *AMERICAN EPHEMERIS*, 1894, FIRST EDITION.

In comparing some meridian circle observations of the star 31 *Comæ Berenices*, made in 1894, with the places given in the *American Ephemeris*, first edition, these last were found to be erroneously reduced. The superintendent has kindly forwarded a copy of the second edition, in which the correction had been noted. Since this does not appear in the lists of corrections for subsequent years, it may be serviceable for those who have the first edition, 1894, to print the places of the star here. Those for λ *Bootis* have also to be corrected, and ephemerides of the two follow.

31 *Com. Ber.* 61° 53′			λ *Bootis.* 43° 25′		
1894.		$12^h\ 46^m$	1894.		$14^h\ 12^m$
Feb.	8.6	$33^s.60$	Mch.	20.6	$23^s.70$
	18.6	33.87		30.6	23.91
	28.6	34.10	April	9.5	24.06
Mch.	10.5	34.29		19.5	24.17
	20.5	34.42		29.5	24.22
	30.5	34.51	May	9.5	24.23
April	9.5	34.57		19.4	24.19
	19.4	34.58		29.4	24.12
	29.4	34.57	June	8.4	24.00
May	9.4	34.52		18.3	23.85
	19.4	34.46		28.3	23.68
	29.3	34.37	July	8.3	23.48
June	8.3	34.27		18.3	23.27
	18.3	34.16		28.2	23.05

The places of these stars are given on pages 371 and 372 of the first edition.

R. H. T.

CHANGES IN THE MERIDIAN CIRCLE CORRECTIONS, AFTER ADJUSTMENT.

In the beginning of October, 1894, the meridian circle was adjusted in level and azimuth, the *plus* values of the corrections being reduced nearly to zero. The list following shows the changes subsequent to adjustment, as determined on observing nights. The level has been obtained over the nadir and checked by the hanging level. The azimuth is closely checked by reading on the Mire, lighted by incandescent lamp; the observation of this last not differing more than $^s.01$, on the average, from the azimuth obtained by circumpolar stars, over long intervals.

It will be noticed that changes set in at once. That of the level is, in general, progressive, and in the same direction as noted at the same season of the year preceding, but more rapid. The azimuth appears to have oscillations, with some dependence upon temperature.

The thermometer reading is the mean temperature of the night of observation, and any discussion of the changes due to temperature will have to take into account the readings at intermediate times.

1894.	Level.	Azimuth.	Temp.	1894.	Level.	Azimuth.	Temp.
	s.	s.	°		s.	s.	°
Oct. 2	—.05	+.19	56	Nov. 5	—.34	+.01	63
3	—.17	+.27	68	6	—.39	—.08	65
4	—.25	+.22	71	7	—.37	.00	67
5	—.29	+.08	67	8	—.40	—.14	65
8	—.28	—.06	64	9	—.43	—.23	64
9	—.29	—.06	63	10	—.42	—.23	67
10	—.33	—.20	58	12	—.43	. . .	65
12	—.32	—.12	60	14	—.44	—.29	71
15	—.30	+.04	71	16	—.39	—.27	55
16	—.30	—.04	64	19	—.42	—.19	61
South	east St	orm.		23	—.43	—.08	56
22	—.16	+.23	53	South	east St	orm.	
24	—.19	+.14	52	28	—.33	—.03	38
25	—.25	+.22	58	30	—.25	+.07	36
29	—.27	+.17	55	. . .	. . .	. . .	. . .
30	—.28	+.14	55	. . .	. . .	. . .	. . .

The collimation correction, as usual, has been very small, and nearly constant. Its value rarely reaches ˢ.01, which is but one-seventh of the thickness of the thread whose position is to be determined.

R. H. T.

THE VELOCITY OF ζ *HERCULIS* IN THE LINE OF SIGHT.

The 3d magnitude star ζ *Herculis* is remarkable for its very great velocity in the line of sight. Dr. A. BELOPOLSKY, the able head of the Pulkowa Observatory Spectroscopic Department, took seven photographs of this star's spectrum in 1893, which showed that the star was approaching the solar system at the rate of 70 kilometers (43 miles) per second. BELOPOLSKY'S result was confirmed by MM. DESLANDRES and MILLOCHAU of the Paris Observatory, who obtained 62 kilometers per second. This is the greatest velocity in the line of sight yet found for any of the bright stars. The star whose known velocity is next in magnitude is α *Tauri* (*Aldebaran*), for which VOGEL and SCHEINER obtained a recession of 48.5 kilometers per second. It should be noted, however, that the solar system is approaching ζ *Herculis* and receding from α *Tauri*, so that the observed velocities of both stars must really be decreased by nearly the amount of the Sun's motion. This probably lies between 10 and 30 kilometers per second.

If we except some of the new stars, which seem to have abnormally high velocities, it is probable that the greatest sidereal velocity in the line of light yet observed is that of the planetary nebula G. C. 4373. Professor Keeler in 1890 showed that this object has a velocity of approach of 65 kilometers (40 miles) per second. The nebula is situated very near the pole of the ecliptic, and its relative velocity is therefore unaffected by the motion of the solar system. W. W. C.

THE ORBITAL MOTION OF δ *Cephei*.

The star δ *Cephei* was discovered to be variable by Goodricke in 1784. It oscillates between the 3.7 and 4.9 magnitudes in $5^{d}\ 8^{h}\ 47^{m}\ 39^{s}$, ascending from 4.9 to 3.7 in about 38 hours and descending to 4.9 in the remaining 91 hours. Dr. Belopolsky of Pulkowa has recently observed the velocity of this star in the line of sight. He has found that the velocity varies in a period coincident with the period of the variation in brightness, and that the star is moving in a very excentric orbit about a dark or relatively dark companion. Thus the variation in brightness is presumably caused by one star eclipsing a part of the other star.
W. W. C.

THE MERIDIAN CIRCLE IN JANUARY.

The following list of corrections, determined on regular observing nights, shows the good performance of the instrument at temperatures comparatively low for Mount Hamilton :

1895.	c.	b.	a.	Zenith.	Temp.
January 25	.00	− .50	+ .08	20″.0	37°
26	.00	− .51	+ .05	20 .3	34
28	+ .01	− .53	− .03	21 .2	32
29	.00	− .54	+ .01	19 .7	44
30	− .01	− .57	− .01	19 .9	44
31	.00	− .59	− .11	20 .1	45
February 1	.00	− .60	− .10	20 .2	47

There is rather large variation in the reading of the zenith point, showing some dependence upon the temperature. Ad-

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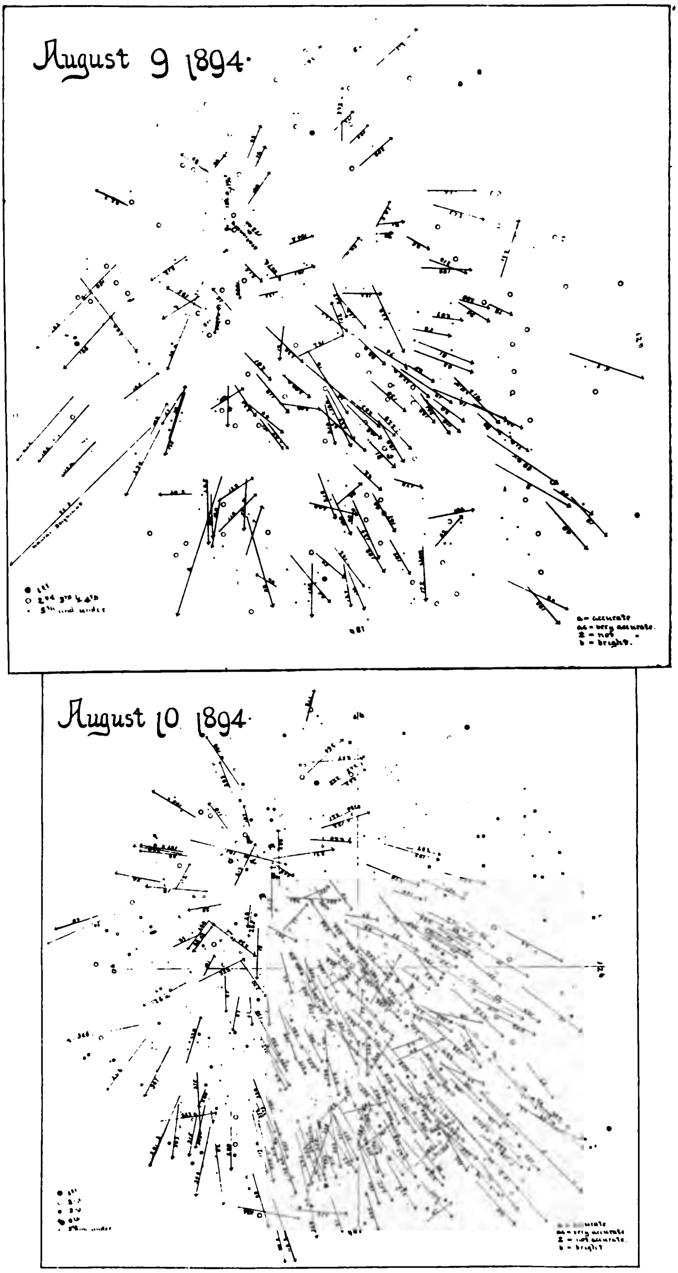

Meteor Paths charted at the Lick Observatory
by C. D. Perrine.

vantage was taken of this period of low temperatures to determine flexure and various other constants for those conditions. The result of series upon three days, for horizontal flexure, at 40°, is 0″.02. This has, however, a probable error of about 0″.10, by independent determination of the sources of error: the difference of the observations of the two collimators, each having a probable error of ± 0″.10, and the error of setting of one collimator upon the other. By extending the observations in each series, smaller nominal errors would appear; but it is preferred rather to take a greater number of series, each short, to avoid sensible changes in the positions of the telescopes, and observed as nearly as possible under the usual conditions. The value of the Declination micrometer at 40° is 48″.15, and that of the Right Ascension micrometer is $3^s.214$. R. H. T.

THE DISCONTINUANCE of *L'ASTRONOMIE*.

We learn with regret that *l'Astronomie*, FLAMMARION'S monthly review of popular astronomy, has been discontinued. In the December number, which was the final number, M. FLAMMARION states that this was necessary on account of difficulties of administration and the insufficiency of his own resources.

W. W. C.

DRAWINGS OF *MARS*.

The drawings of *Mars* (frontispiece), made at the opposition of 1894, with the 36-inch equatorial, using magnifying powers of 350 and 520 diameters, have been selected from my numerous sketches in such a way as to show all the surface of the planet, except the invisible north polar regions. In general, no attempt was made to draw the details which were visible near the limb of the planet. W. W. C.

A 48-INCH TELESCOPE.

The *Bulletin* of the Astronomical Society of France is authority for the statement that work has actually commenced on a 48-inch refracting telescope. The length is understood to be in the neighborhood of 200 feet. It is reported that the instrument is to be completed in time for the Paris Exposition of 1900.

W. W. C.

THE RADCLIFFE CATALOGUE FOR 1890.

This catalogue contains the positions of 6424 stars, from observations made at the Radcliffe Observatory, Oxford, under the direction of E. J. STONE, formerly Director of the Royal Observatory, Cape of Good Hope.

The list is intended to include all stars, down to the 7th magnitude, from the equator to 25° South Declination. In general, three observations have been given to each star, besides the much larger number for the fundamental stars, used for the determination of clock error and instrumental errors. The observations were made during the fourteen years from 1880 to 1893, inclusive, and have been reduced to the epoch 1890. The precession and secular variation are given for every star; and proper motion, when it appears to exist, by comparison with other catalogues.

The Right Ascensions depend upon the lists of the Greenwich Observatory, corrected by a constant obtained from observations of the Sun, extending over the greater part of the period.

The Declinations, or North Polar Distances of the catalogue, are obtained from observations of the zenith point, with a constant value of the N. P. D. of the zenith.

A comparison of the places deduced from upper and lower culminations, would indicate, as needed, a diminution of BESSEL'S refractions of 0.0035.

This, it may be noted, would bring the refraction corrections nearly into accord with those of the Pulkowa tables, which are based upon a constant 0.0027 less than that of BESSEL.

R. H. T.

THE ASTRONOMICAL PRIZES OF THE FRENCH ACADEMY.

The Astronomical prizes of the French Academy of Sciences for the year 1894 have been awarded as follows:

The LALANDE prize, value, 540 francs, to M. JAVELLE, an astronomer in the Nice Observatory, for his observations of faint nebulæ with the 30-inch equatorial. Since 1890, M. JAVELLE has discovered and accurately determined the positions of 1100 nebulæ in the zone comprised between Declinations + 30° and — 15°.

The DAMOISEAU prize, value, 1500 francs, to M. BRENDEL, for perfecting methods of rapidly calculating approximate values of the perturbations of the small planets for long intervals of time.

The VALZ prize, value, 460 francs, to M. CONIEL, a computer in the French Bureau of Longitudes, for the calculation of the orbits of 13 asteroids, and for other valuable computations.

The JANSSEN prize, a gold medal, to Professor GEORGE E. HALE, Director of the YERKES Observatory, University of Chicago, for successfully photographing the solar faculæ and prominences with the photoheliograph; for establishing an important new observatory, and for liberally contributing his personal resources to the needs of science. W. W. C.

A BRIEF REVIEW OF FROST'S TRANSLATION OF SCHEINER'S "DIE SPECTRALANALYSE DER GESTIRNE." *

About the year 1888 astronomical spectroscopy began to undergo a remarkable development. This development was characterized by rapidity, completeness and accuracy. It was due to several causes, among which we may mention: the application of photography; the construction of large telescopes; spectroscopes planned to yield the maximum efficiency in the particular lines of work undertaken; and, above all other causes, systematic work. As examples of this, it is sufficient to mention: VOGEL'S photographic determinations of stellar motions in the line of sight, by means of a spectroscope specially designed for that problem; the wholesale discovery of interesting and important objects by means of their photographed spectra at HARVARD College Observatory; ROWLAND'S improvements in diffraction gratings and his work on the solar spectrum; and KAYSER and RUNGE'S accurate determinations of wave-lengths in the spectra of the elements.

In the old astronomy the attainment of accuracy in making observations required that corrections for refraction, parallax, etc., be rigorously applied, and led to greater refinements in all lines of investigation. The working astronomer was obliged to use a great variety of formulæ in reducing his observations and in utilizing his own and previous results. Such handbooks as BRÜNNOW'S and CHAUVENET'S, WATSON'S and OPPOLZER'S,

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* A treatise on Astronomical Spectroscopy, being a translation of "Die Spectralanalyse der Gestirne," by Professor Dr. J. SCHEINER, assistant at the Royal Astrophysical Observatory at Potsdam. Translated, revised and enlarged, with the coöperation of the author, by EDWIN BRANT FROST, M. A., Assistant Professor of Astronomy in Dartmouth College, Boston, 1894. GINN & Co.

fortunately became available for his use. Similarly, the attainment of accuracy and the employment of new methods in celestial spectroscopy led every working astrophysicist to feel the pressing need of a handbook which would contain all the necessary formulæ, theories and results of previous observations, in a shape convenient for use. Up to 1890 there was no such book. Just as an elementary descriptive work on astronomy, intended for the high-school or for popular reading, is not adapted to the requirements of the working astronomer, so the excellent popular treatises on spectrum analysis by ROSCOE and by SCHELLEN are not of much use to the investigator in astrophysics. Happily, Professor SCHEINER, in 1890, was impelled to undertake the preparation of a book which should satisfy the requirements of the investigators; and, in his "Die Spectralanalyse der Gestirne," he succeeded admirably. The experience and position of the author, as Professor VOGEL'S assistant at Potsdam, enabled him not only to include those methods and principles required in refined work, but also to assign, with very few exceptions, the proper weight to observations made elsewhere. Those are the two most important characteristics of the book; characteristics, by the way, which can come only from long experience in making observations.

The hearty reception given to Professor SCHEINER'S handbook induced Professor FROST to increase its usefulness to the large number of English-speaking people who are interested in the subject, by translating, revising and enlarging it. The translating, which has been admirably done in pure and simple English, is but a small part of the work. The necessary revision was slight. It was in adding the results obtained in the years 1890–1893 inclusive that the principal task of the translator lay. That there have been great advances since 1890 is best shown by going through the book and marking those parts added by Professor FROST. That the translator has added the new matter most skilfully and judiciously is shown by the homogeneity of the old and the new portions. A list of the principal additions made by FROST is very encouraging. They are

(1) The properties of ROWLAND'S concave gratings.

(2) MICHELSON'S interference methods of spectroscopic measurements.

(3) HALE'S spectroheliograph, and his photographs of the solar faculæ and prominences.

(4) ROWLAND'S table of chemical elements present in the Sun.

(5) Extension of YOUNG'S table of chromospheric lines into the ultra-violet, by HALE and DESLANDRES.

(6) New lines observed at the LICK Observatory in nebular spectra.

(7) HARVARD College Observatory list of stars containing both bright and dark hydrogen lines.

(8) BELOPOLSKY'S studies on β *Lyræ.*

(9) WOLF-ROYET stars discovered at HARVARD College Observatory, and their spectra as observed at LICK Observatory.

(10) Observations of *Nova Auriga* at various observatories.

(11) Theories of new stars.

(12) Tables for the reduction of spectroscopic observations of motions in the line of sight.

(13) The Potsdam list of stellar motions in the line of sight.

(14) KEELER'S motions of nebulæ in the line of sight.

(15) ROWLAND'S new tables of standard wave-lengths in the solar spectrum, replacing the Potsdam list.

(16) KAYSER and RUNGE'S wave-lengths of selected lines in the arc-spectrum of iron, replacing THALÉN'S list.

(17) YOUNG'S partial revision of the chromospheric lines.

(18) Extensions in nearly every direction.

The book is divided into four parts:

Part I relates to Spectroscopic Apparatus, such as prisms, cylindrical lenses, slits, micrometers, gratings, etc., and describes a few of the principal spectroscopes now in use.

Part II, relating to Spectroscopic Theories, treats first of KIRCHHOFF'S law of the relation existing between emission and absorption phenomena of light; and, secondly, of DOPPLER'S principle of line displacements due to motion in the line of sight.

Part III, taking up nearly one-half the volume, is an admirable statement of the Results of Spectroscopic Observations. It treats of the Sun, Planets, Comets, Nebulæ, the Stars, the Aurora and

Zodiacal Light, the determinations of motion from the Displacement of Spectral Lines.

Part IV contains Spectroscopic Tables.

An Appendix, of 46 pages, is a Bibliography of Astronomical Spectroscopy.

While the work is intended as a handbook for investigators and as a text-book for special students, the general student of astronomical spectroscopy will find the whole of Part III, and many other portions, to be of great interest to him. Of the book as a whole, and of the treatment of details, there is very little to criticise adversely. There are a few minor points, however, which might be improved, or might mislead the general reader, and we shall point them out:

First.—The book would be better adapted to the requirements of students if methods of adjustment, principles concerning the efficiency of spectroscopes and other data were more systematically presented.

Second.—We miss descriptions of many recent spectroscopes and details of apparatus which are unquestionably of greater utility than some of those which are minutely described.

Third.—In the treatment of the spectrum of the solar corona, there is no mention of the diffraction effect as observed by HASTINGS and KEELER. The chapter on the Sun is very incomplete, probably necessarily so, and we are led to wish that YOUNG'S excellent book on "The Sun" was brought up to date.

Fourth.—The student who wrestles with portions of the last paragraph on page 198 must wrestle indeed. Why not change "more refrangible" to "less refrangible," and omit the remainder of that paragraph? These points are contained both in the German text and translation.

Fifth.—The last paragraph on page 199 contains some statements which are not established.

Sixth.—LOCKYER is entitled (on page 228) to the credit of first photographing some of the hydrogen lines in the *Orion* nebulæ, in February, 1890.

Seventh.—The bright $H\beta$ line in ϕ *Persei* (on page 257) was first observed, I believe, by ESPIN. The $H\alpha$ line was also observed to be bright at LICK Observatory in 1892.

Eighth.—It seems to me that some of the difficulties in the way of explaining the spectrum of *Nova Aurigæ* have not received adequate recognition. For instance, the large amount of detail shown on BELOPOLSKY's negatives, described on page 289, is not to be explained away by Professor VOGEL's suggestion that it may be due to changes in the spectroscope during the exposure. BELOPOLSKY's comments on that suggestion, in *Astronomische Nachrichten*, No. 3184, make it exceedingly probable that the details are real features of the spectrum. May they not be accounted for by the fact that BELOPOLSKY used greater dispersion than the other observers? Again, some of VOGEL's photographs show that the different hydrogen lines were not alike in structure and in displacement. Compare, for instance, his Hδ and Hε groups of March 3d and 4th. The displacements are very different. These, and other important difficulties, have not yet been adequately considered.

Ninth.—The Bibliography of Astronomical Spectroscopy in the German original had its usefulness seriously impaired by the *extraordinary* number of errors it contained. The translator has removed many of the errors, but, unfortunately, several still remain. For example, on page 448, "COPELAND, R. The spectrum of comet 1882a. Copernicus **2**, 255." should read "COPELAND, R. Spectroscopic observations of comets III and IV, 1881; comet I, 1882, and the great comet of 1882. Copernicus **2**, 225–245." Likewise, on page 452, line 19, the numbers "363–394" should be "366–370."

The portions of the book relating to comets passed through the press too early to include the photographic spectra of comets *b* 1893 and *b* 1894, which extend our knowledge in that direction very considerably. It is likewise unfortunate that the 1893–'94 observations of the *Orion* nebula and the stars contained in it could not be utilized in the translation. The recent observations of *β* and *ε Orionis* show that the interesting line D_3 is dark in those stars—a fact which controverts the statement in lines 6–7, page 251.

While the responsibility for the treatment of all observations made since 1890 rests upon Professor FROST, an opportunity was given to Professor SCHEINER, in the preface, to express his dissent from FROST's views, and to make additional comments. Some of SCHEINER's notes are very suggestive and valuable. One cannot avoid being surprised, however, by his unsafe logic used in note (7). Dr. SCHEINER does not believe it possible that dark lines can exist in the spectrum of γ *Cassiopeiæ*, as none have ever been seen in numerous photographs taken at Potsdam! Nevertheless, dark lines have been observed visually and photographically by KEELER, photographically at HARVARD College Observatory, and photographically at LICK Observatory.

Similarly, the doubts expressed by Professor SCHEINER, in notes (1), (8), (9), will not be sustained; on the contrary, the statements made by the translator will prevail.

While, perhaps, more attention has here been called to the book's weak points than to its strong points, my criticisms have not been made in any hostile spirit. The points which can be criticised unfavorably constitute an exceedingly small part of the book. The translation takes its place as the standard work, not only in English-speaking countries, but in all countries where astrophysical studies are prosecuted. The volume should be found in the library of every one who is interested in the details of celestial spectroscopy. W. W. C.

CHANGE IN THE LATENT IMAGE OF AN EXPOSED DRY PLATE.

In October, 1894, while developing some CARBUTT B plates which had been exposed on the Sun in the months of June to October, I was led to suspect a change in the latent photographic image, and some of the same plates were exposed on November 1, for the purpose of determining the matter. These experimental plates were developed on January 15 and February 1. They show that the image had entirely disappeared in all except one case, and that was *extremely* faint. Every precaution was taken to eliminate accidental changes. From two exposures on the same plate, made November 1, 1894, and February 2, 1895, with the images overlapping, it is apparent that the exposed part fully recovered its sensitiveness in the interval, as the later exposure was of full density (including the portion which lapped over the first exposure); the first image being extremely faint. The change may be peculiar to that particular kind of plate or lot of plates, as a similar exposure on a CARBUTT A plate seems to show no such change. C. D. PERRINE.

LICK OBSERVATORY, February 2, 1895.

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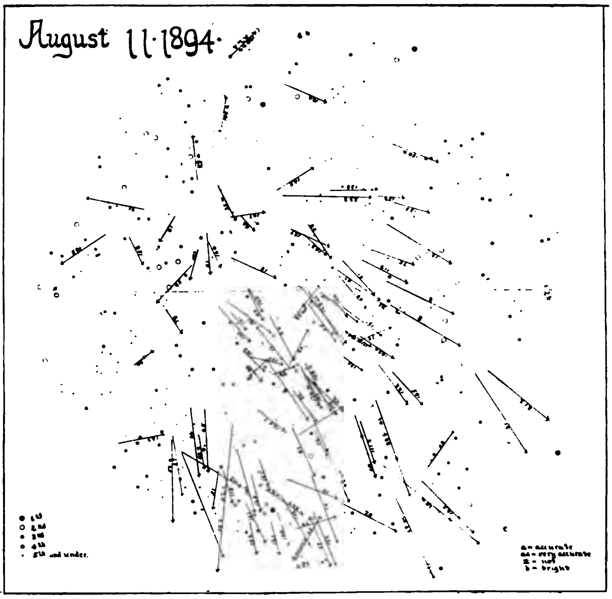
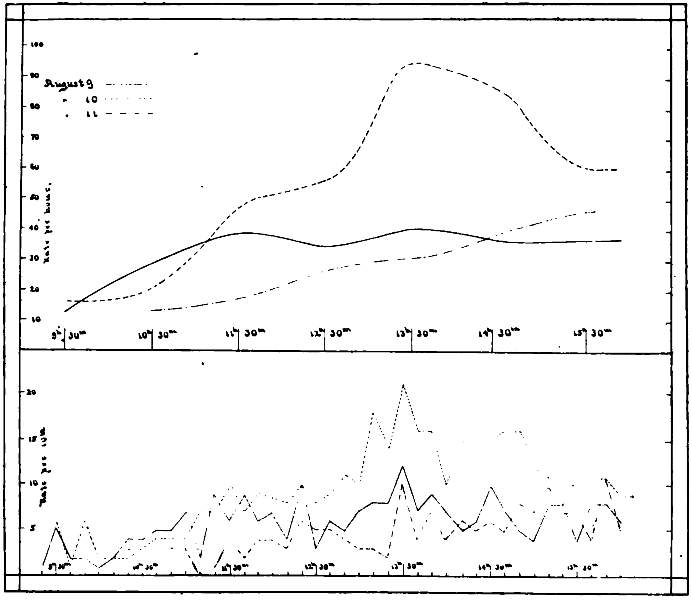


Meteor Paths charted at the Lick Observatory
by C·D·Perrine·



Frequency Curves of Meteors, from observations at the
Lick Observatory on August 9, 10, 11, 1894. Deduced by A. F. Poole.

ILLUSTRATIONS OF THE AUGUST METEORS OF 1894, AS OBSERVED AT THE LICK OBSERVATORY.

On page 294 of the previous publication is a note by Professor HOLDEN on the observations of the August meteors of 1894. The charts drawn by Messrs. COLTON and PERRINE showing the paths of the meteors observed by them at Mount Hamilton, and the diagram of frequency-curves compiled by Mr. POOLE, are reproduced in miniature in this number. It is, perhaps, to be regretted that the scale is so small; the illustrations will, however, convey a good general idea of the work which was done. The reduction of the observations will be made with the aid of the original charts, which are on so large a scale as to meet every requirement. J. M. S.

LICK OBSERVATORY, February 4, 1895.

SLIGHT EARTHQUAKE.

On the night of February 4 a shock of earthquake was noticed, which it was possible to observe with an accuracy rarely attained. I was using the meridian circle, and noted the time of the tremor by the position of the star between the transit wires. The tremor lasted barely one second, and was recorded at $6^h\ 28^m\ 40^s$ by the chronograph, with sidereal clock No. 4. This, reduced to Pacific Standard mean time, is $9^h\ 34^m\ 41^s.9$. The shock was of a shaking character, distinct enough to render the observer decidedly uncomfortable for the moment. No effect has been detected in the adjustments of the instrument, determined before and after; and the clocks have kept their normal rates.

R. H. T.

ERRATUM.

In the article, "Corrections to HUSSEY'S Logarithmic Tables," in No. 38, page 299 of these *Publications*, the proof-reader is responsible for an error which should be corrected.

For 29.9853, *read* 299853.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS, HELD IN THE ROOMS OF THE SOCIETY, JANUARY 26, 1895, AT 7:30 P. M.

President **Campbell** presided. A quorum was present. The minutes of the last meeting were approved. The following members were duly elected:

LIST OF MEMBERS ELECTED JANUARY 26, 1895.

Colonel E. D. **Boyle**	Gold Hill, Storey Co., Nev.
Rev. E. B. **Brady**	628 California St., San Francisco, Cal.
Miss S. J. **Eastman**	Ogontz School, Pa.
Mr. C. L. **Foster**	601 Polk Street, San Francisco, Cal.
Mr. W. H. **Hammon**	U. S. Weather Bureau, Mills Building, San Francisco, Cal.
Mr. **Jackson Hatch**	Porter Building, San José, Cal.
Hon. **Gardiner G. Hubbard**	1328 Connecticut Avenue, Washington, D. C.
Mr. **Chester E. Pond**	Auburn, Cal.

Adjourned.

MINUTES OF THE MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD IN THE LECTURE HALL OF THE CALIFORNIA ACADEMY OF SCIENCES, JANUARY 26, 1895.

The meeting was called to order by President **Campbell**. The minutes of the last meeting were approved. The Secretary read the names of new members duly elected at the Directors' meeting.

A committee to nominate a list of eleven Directors and Committee on Publication, to be voted for at the annual meeting to be held on March 30, was appointed, as follows: Messrs. F. H. **McConnell** (Chairman), J. C. **Cebrian**, J. A. **Lighthipe**, **Chas. S. Cushing** and **Camilo Martin**.

A committee to audit the accounts of the Treasurer, and to report at the annual meeting, was appointed, as follows: Messrs. G. R. **Lukens**, S. C. **Passavant** and O. **von Geldern**.

The following papers were presented:

1. Georgetown College Observatory, 1843–1894, by Rev. Father **Fargis**, S. J.
2. Observations of the Transit of *Mercury*, by Messrs. R. G. **Aitken** and A. F. **Gillihan**.
3. The **Lowe** Observatory, by Mr. C. D. **Perrine**.

4. Photography of Comets, illustrated with lantern slides, by Professor W. J. HUSSEY.
5. Sun-spots, with lantern slide illustrations, by Mr. C. D. PERRINE.
6. Observations of the Transit of *Mercury*, by Hon. E. S. MARTIN, of Wilmington, N. C.
7. Review of Professor KEELER'S 1890 Spectroscopic Observations of Nebulæ for Motion in the Line of Sight, by Professor B. HASSELBERG.
8. The Sun's Motion in Space, by Mr. W. H. S. MONCK.

Mr. C. D. PERRINE, Secretary of LICK Observatory, presented a paper on Sun-spots, treating of their discovery early in the seventeenth century, of their development as individual spots or related groups of spots, of their development as a whole according to the periodic law of Sun-spots, and of the various theories to account for their origin. Mr. PERRINE'S paper was illustrated with about forty lantern slides prepared mostly from his negatives of the Sun made at Mount Hamilton.

Professor W. J. HUSSEY'S paper on the Photography of Comets contained the results of his systematic examination of the photographs of the recent bright comets, especially of Comet *b* 1893, of which he obtained several excellent negatives. Mr. HUSSEY brought out some most important facts in regard to the streamers and condensations forming the tails of comets. His paper was illustrated with thirty lantern slides.

The papers by Messrs. PERRINE and HUSSEY will be printed soon in these *Publications*, probably in the April number.

OFFICERS OF THE SOCIETY.

W. W. CAMPBELL (LICK Observatory),	*President*
W. J. HUSSEY (Leland Stanford Jr. University, Palo Alto, Cal.), WM. M. PIERSON (Mills Building, S. F.), JOHN DOLBEER (10 California Street, S. F.),	*Vice-Presidents*
C. D. PERRINE (LICK Observatory),	*Secretary*
F. R. ZIEL (410 California Street, S. F.),	*Secretary and Treasurer*

Board of Directors—Messrs. ALVORD, CAMPBELL, DOLBEER, HOLDEN, HUSSEY, MOLERA, PERRINE, PIERSON, SCHAEBERLE, VON GELDERN, ZIEL.

Finance Committee—Messrs. PIERSON, DOLBEER, VON GELDERN.

Committee on Publication—Messrs. HOLDEN, CAMPBELL, YALE.

Library Committee—Messrs. VON GELDERN, MOLERA, BABCOCK.

Committee on the Comet-Medal—Messrs. HOLDEN (*ex-officio*), SCHAEBERLE, BURCKHALTER.

OFFICERS OF THE CHICAGO SECTION.

Executive Committee—RUTHVEN W. PIKE.

OFFICERS OF THE MEXICAN SECTION.

Executive Committee—CAMILO GONZALEZ, FRANCISCO RODRIGUEZ REY, AGUSTIN ARAGON.

NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the *calendar* year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our book-keeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific 819 Market Street, San Francisco.

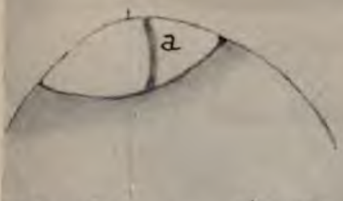
It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 819 Market Street, San Francisco, who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed rests with the writers, and is not assumed by the Society itself.

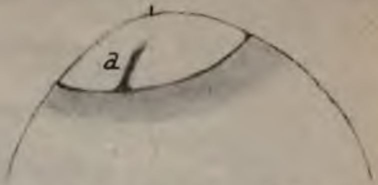
The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend any or all of the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific" at the rooms of the Society, 819 Market Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

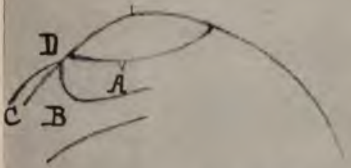
PUBLICATIONS ISSUED BI-MONTHLY.



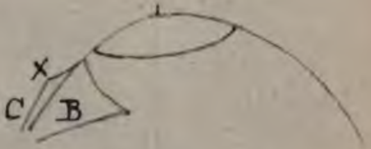
1894, June 12, $15^h 30^m$.
$\lambda = 172^\circ.7$; $\phi = -23^\circ.7$.



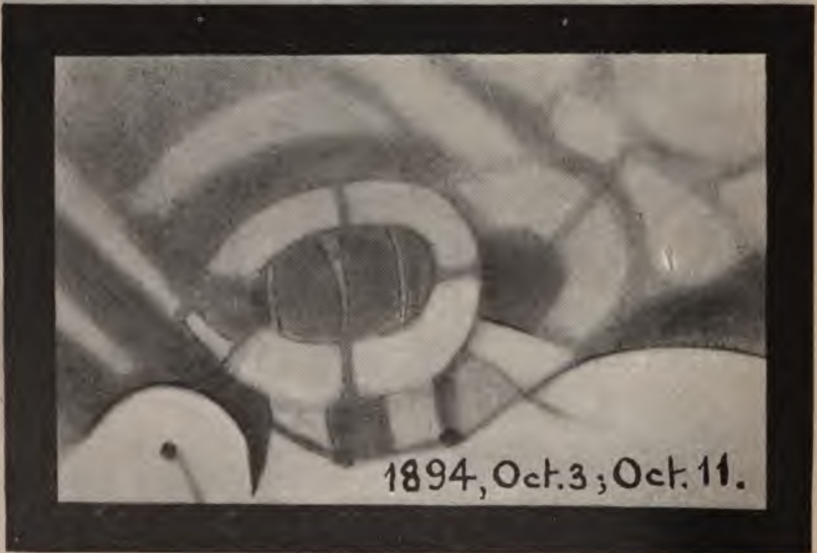
1894, June 12, $16^h 0^m$.
$\lambda = 179^\circ.9$; $\phi = -23^\circ.7$.



1894, June 26, $15^h 15^m$.
$\lambda = 31^\circ.7$; $\phi = -23^\circ.2$.



1894, June 26, $15^h 25^m$.
$\lambda = 34^\circ.2$; $\phi = -23^\circ.2$.



1894, Oct. 3; Oct. 11.

MARS, 1894, BY EDWARD S. HOLDEN.

PUBLICATIONS

OF THE

Astronomical Society of the Pacific.

VOL. VII. SAN FRANCISCO, CALIFORNIA, APRIL 1, 1895. NO. 41.

ADDRESS OF THE RETIRING PRESIDENT OF THE SOCIETY, AT THE SEVENTH ANNUAL MEETING, MARCH 30, 1895.

By W. W. CAMPBELL.

That there is greater public interest taken in astronomy than in any other department of science may be accepted without question. That fact is manifested by the gifts of money for establishing and supporting observatories; by the number of visitors to observatories; by the demand for astronomical literature in the newspapers; and by the large membership of our astronomical societies.

This being true, it is important that correct ideas should exist of what astronomers are trying to do. Visitors to observatories are intensely interested to learn the nature of our work, but not one in a score has a definite idea on that subject. A general opinion prevails that it is the duty of an astronomer to sweep the heavens with his telescope, in order to find new bodies—comets, planets, new stars, etc. While we in no way discourage the search for new and unknown objects, we may say that, relatively, very few professional astronomers engage in that work, either systematically or occasionally. The great observatories, with their expensive equipments, cannot afford to engage in such uncertain work. They leave it either entirely to the small observatories or to the amateur astronomer, or else they make it a very subsidiary matter. Thus the LICK Observatory devotes, possibly, one-twenty-fifth of its energies, but much less than one-twenty-fifth of its equipment, to looking for new objects. Similarly the other great observatories — Greenwich, HARVARD, Paris, Pulkowa, Washington — are doing little or nothing in that line.

The large majority of our unexpected comets are discovered by private or amateur astronomers. The expected returns of periodic comets are largely detected by professionals, for the double reason that they know when and where to look for them without great loss of time, and it is generally an advantage to search for them with large telescopes, which, unfortunately, amateurs do not possess.

"New stars" constitute a field of superlative importance. It is open alike to professionals and privates. Of the five new stars discovered since 1866, three are due to amateurs, and two to professionals.

Seven satellites of our solar system have been discovered in the last fifty years. The first of these, *Hyperion*, was discovered by a HARVARD College observer, and, independently, two days later, by a private astronomer in Liverpool. Of the other six, three were discovered in this country by professionals, and three by the Liverpool private observer. Yet, this is a field open only to large telescopes, and is not a fair test of the efficiency of private work.

The history of variable stars is similar to that of comets and new stars. The random searching for variable stars is nearly all done by private observers. They have very many discoveries to their credit. Nearly all of the observations for determining their periods and other circumstances of variation are made by private means.

In a similar manner, we could multiply cases showing the commendable activity of private observers in searching for new and unexpected objects, and, at the same time, showing that this field is not occupied by many professionals.

It may be asked: If these subjects may be, and are, left so largely to private observers, what is left for the professionals? Nearly everything is left to the latter. The astronomer's work has only just begun when the new object is discovered. Besides, there are the more interesting and valuable old and well-known bodies which are furnishing us an infinite field for investigation.

Professor SEDGWICK has given us one of our best definitions of scientific work. It runs something like this: Scientific work consists in the collection of facts and numerical results, and their arrangement in such a form that the general principles and laws of the science become apparent. That may be taken as the guiding principle of every astronomer. It matters little if new stars, comets, nebulæ, variable stars, are simply discovered. Unless they are investigated, the science of astronomy is not advanced. It is as if EUCLID had discovered that there is a science of the circle and the sphere, but had not investigated its laws. It is as if NEWTON and LEIBNITZ had discovered that there is a process in mathematics which we call the calculus, but had stopped before developing its general principles. It is as if the chemist had discovered that there is an element called oxygen, but had stopped before deducing its properties. It is as if COPERNICUS had been contented, like his neighbors, in noting the existence of the principal heavenly bodies, and had not investigated their motions. The laws of geometry, of calculus, of chemistry, of astronomy, have always existed. They are a part of general truth. The scientist does not invent them. He finds them out by investigating in those fields, and makes advances, as SEDGWICK pointed out, by the collection and systematic study of facts and numerical results.

The aim of astronomical science is analogous to that of biological science. The greatest problem presented to Darwin, to his predecessors and successors, is that of the history of organic life. It embraces not only a full knowledge of every form of life that exists, or that ever existed, but, most of all, of the relations existing between the different grades and forms. In the same way we may say that the ultimate problem of astronomy is that of the history, on a large scale, of inorganic life—of the sidereal universe. The Sun, the planets, their satellites, the comets, the meteors, the zodiacal light, are before us to be investigated. In the sidereal system we have tens of millions of stars, tens of thousands of nebulæ, star clusters, and double stars. We want to know every possible fact about these objects, not for the sake of the facts themselves, but because of the general principles which they will enable us to discover. We want to know their past history, their present condition, the future in store for them. We want to know their origin and end, and, most of all, we want to know how the different classes of objects are related to each other.

It is quite impossible to explain in detail how the astronomer conducts his investigations, but one or two examples will be given in outline.

Let us take the case of a comet. Its discovery, together with its position in the sky, is announced by telegraph to all the observatories which are known to desire that information, and those interested in cometary astronomy carry on the particular investigations for which they have suitable apparatus. In the first place, there are generally very many observers who determine from night to night the positions occupied by the comet. The first half-dozen, or more, observations are published as speedily as possible, the American observations being generally sent by telegraph to Cambridge, Mass. The first three observations secured on different dates are used by some skilled computer, who in a few hours computes an approximate orbit of the comet, determines the approximate positions in which it will be found in the next few weeks, and sends the information by telegraph to the observatories. The position of the comet continues to be observed, and a more accurate orbit is computed. We soon learn whether the comet is moving through the solar system in a parabolic orbit, never to return to us, or whether it is moving in an ellipse, and is, therefore, to remain with us as a somewhat permanent member of our system. If it is a periodic comet, is it identical with any comet previously observed? If so, the circumstances of its motion in the intervening time are fully discussed. If it is a periodic comet not previously observed, there exists the question of its origin. Was the comet on its passage through our system moving near enough to any of the large planets—*Jupiter*, *Saturn*, etc.—to be captured by them and by the Sun, as many of our periodic comets probably were, and compelled to remain in our system?

The positions of the comet continue to be observed with the utmost accuracy, as long as it remains visible. After its disappearance, all these observations are made use of by an experienced computer, who determines, by processes usually requiring several months' labor, the best possible orbit of the comet, discussing every circumstance of its motion. If it is a faint parabolic comet, moving away never to return, the subject of cometary astronomy is not advanced appreciably by all these careful observations and computations. There are dozens of such comets which have come and gone without telling us anything new, and one is almost unguarded enough to wish that they would remain undiscovered. That is not the case, however; astronomers do not regret the time and energy devoted to the work, and one does not know beforehand how useful his labors may be.

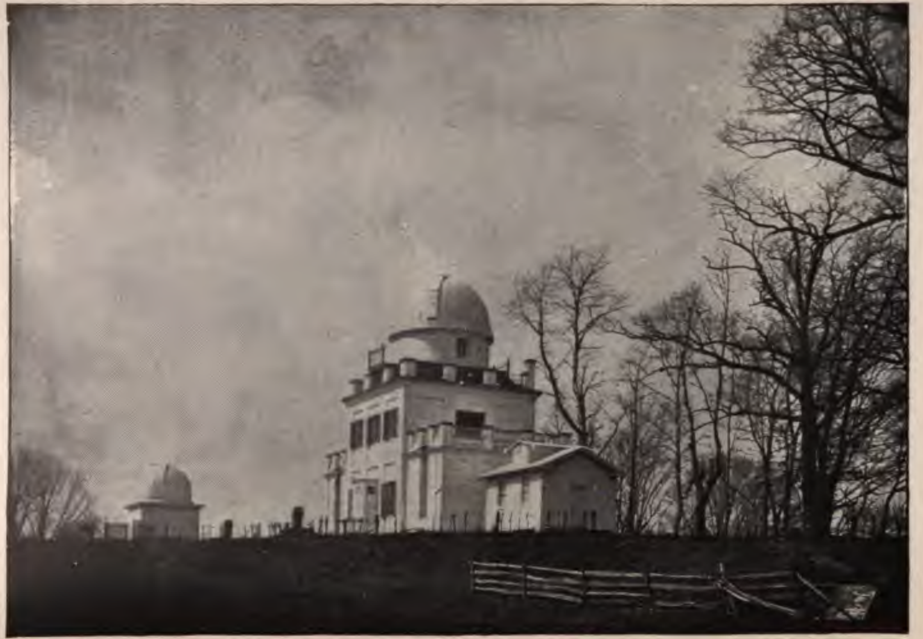
If the comet is a bright one, it is further investigated in many ways. A few years ago its form and appearance would have been accurately drawn. Now it would be photographed as often as possible. The photographic record of its progress from a distant faint object to a bright and complex near object, together with its subsequent decline, would be made as complete as possible. These photographs would be measured and studied to see if they would yield up the secrets of the mysterious comet-forms. The comet would be observed with the spectroscope to determine its condition and its constitution. Its spectrum would be accurately measured and photographed, and compared with all other spectra which could possibly shed any light upon its constitution. It would be observed with the polariscope to determine whether its light is inherent or reflected. Not only would the individual comet be investigated in as many directions as possible, but there remains the study of comets in general. The facts gathered by observers about all comets would be arranged with great skill, to see if the general principles concerning them could be recognized. We want to understand the origin of comets, but we know little or nothing as to how they originate. We want to learn how they form their tails; why the forms of the tails should change so rapidly; why they should be repelled by the Sun; — but as yet we know little or nothing along those lines. We want to know their physical condition and their chemical constitution. We still have many unsettled questions in those fields of inquiry. We would like to know how comets are related to other classes of celestial objects — to the nebulæ, for instance. What is the place of comets in the line of sidereal evolution? In regard to the last question, we know that some of our meteor streams have resulted from, and are, the remains of disintegrated comets, and that is about the extent of our knowledge.

The preceding suggestions indicate a few of the lines in which comets would be studied. There would not be space in this paper to give even a small fraction of the detailed questions which we would ask and try to answer in regard to a bright comet, and comets occupy only a small corner in the astronomical field. They excite great interest, not only because they are extremely interesting objects in themselves, but because they come close to us, and because, since they come and go, they must be studied while they are here. We overlook, sometimes, the greater importance of the old and well-known objects, because they are always with us. These familiar objects illustrate world-life in essentially all its stages of development. Do we want to acquire the secrets of the stars? If so, we must begin by studying our Sun. The Sun, though not one of the largest stars, happens to be the nearest star. There are observatories established for the sole purpose of investigating the Sun, and a great many observers are constantly employed in its visual, photographic, thermal, and spectroscopic study. Eclipse expeditions are sent to all quarters of the globe to observe the Sun's corona. Solar research has already resulted in numerous important discoveries, but many of the old questions are still unanswered, new questions are coming up, and the work is still in its infancy. How much more difficult and more extensive must be the study of the distant suns and the nebulæ. They are to be investigated at every point. Let me give an outline of the methods used by an astronomer at one point. We want to know how the nebulæ are related to the stars. We know that, by the operation of natural laws, the nebulæ must be radiating heat into the cold surrounding space, and we think they must be contracting in size. It is a working hypothesis that stars are formed by the condensing of nebulous matter. In the great nebula of *Orion* there are to be seen some interesting groups of stars, which it is suspected may be situated within the nebulous matter. Are those stars actually associated with the nebula,—formed from it, so to speak,—or do we simply see them projected upon the nebula because they happen to lie between us and the nebula, or on the other side of the nebula? The astronomer who wants to settle that question does not sit at the end of his telescope and wait for the nebula to change before his eyes, nor for a new star to be formed. It probably requires thousands, and possibly tens of thousands, of years for appreciable changes to occur. He must study the nebula as it is at present, and the stars just as they are at present. The observer puts his spectroscope on the telescope, not to make an immediate discovery, but to begin an investigation requiring, possibly, a dozen or more nights' work. He enters the dome each night, not in the expectation of settling the question, but to carry out a program of work which he has previously arranged. He will investigate the spectra of the nebula and of each of the stars in question as fully as possible. When all the facts have been secured, he will compare the spectra with each other, noting the coincidences and the discordances. The spectra will prove to be closely related. They support the theory that the stars — that those stars, at least,— have been formed from nebulous matter. But can we say that those stars are situated within the *Orion Nebula?* No; because there are stars in other parts of the sky possessing similar or identical spectra. The *Orion* stars which are in question may be within the present *Orion Nebula*, or they may have been formed from the outer portions of the *Orion Nebula* when that nebula was vastly larger than it is at present; or they may have been formed from other nebulæ which happened to lie in that direction, either between us and the *Orion Nebula*, or beyond the *Orion Nebula.*

I wish it were possible to give here an idea of the valuable and extensive investigations which have been made with meridian instruments, and to outline the methods of work. Until a few years ago, at least one-third of the energies of astronomical workers was devoted to making and reducing observations with the meridian circle. Those observations have given us our star catalogues, containing the accurate positions of a hundred thousand stars, and the approximate positions of five times as many. These star catalogues are the foundation and the framework on which all accurate mathematical astronomy is built, and it is impossible to overestimate their value. This work, requiring great skill, infinite patience, unending toil, is almost wholly unknown to the public, and yet it is astronomy's richest possession.

In whatever line of investigation an astronomer is engaged, it is the inviolable rule to work with the utmost accuracy, even though such accuracy may seem superfluous. We can never tell what great discovery is lurking beneath the surface, ready to be buried by careless observations, and equally ready to be uncovered by refined observations. The greatest recent discovery in astronomy, the variation of terrestrial latitudes, would not have been possible had not our meridian-circle observers striven for the utmost accuracy. The fact that the latitude of a point on the earth's surface varies was revealed by observations made for an entirely different purpose, viz.: for the accurate determination of the positions of stars in the sky. The newly discovered element in our atmosphere, argon, admirably illustrates my point. Its discoverer was engaged in determining the specific gravities of the permanent gases with greater accuracy than had hitherto been attained. In the course of his work, he found that nitrogen taken from the atmosphere was about half of one per cent. heavier than nitrogen taken from definite chemical compounds. An investigation of the possible causes of the discrepancy led to the discovery of the heavier element, argon, combined with the atmospheric nitrogen. Early in the present century, some noted astronomers held, and even expressed, the opinion that the Sun-spots occur at random, without reference to any law; yet, a private astronomer, by observing them accurately and systematically for 40 years, came easily upon the 11-year periodic law of Sun-spots.

Those of our members who have telescopes, some leisure, and great zeal, can, as pointed out at the beginning of this paper, do useful work by discovering new objects. The fields which are open to the private astronomer for pure investigation are more limited, but they are limited only by his personal opportunities. We need only to recall the excellent work of many private astronomers to realize that fact. There is always the question of how to begin. Perhaps I may close this paper with the suggestion that a good way to begin, possibly the best way, is by doing what some other astronomer has already done, or by reviewing and repeating all the observations along a certain line. One will very soon find related fields of work still unexplored, and will have acquired the ability to enter them successfully. That the researches undertaken by the private astronomers in this Society may be many, and be limited only by their opportunities, is the best wish of the retiring President.



OBSERVATORY OF GEORGETOWN COLLEGE.

GEORGETOWN COLLEGE OBSERVATORY, 1843–1893.

By G. A. Fargis, S. J.

In 1841, the Faculty of Georgetown College decided to erect and equip an observatory, in which practical instruction in astronomical work could be given to such students as showed any aptitude or inclination for this particular branch. As the undertaking was chiefly the suggestion of the late Rev. James Curley, S. J., at that time Professor of Physics at the College, to him was entrusted the duty of choosing a convenient site and preparing plans for building and equipment. An elevated spot, about 400 yards almost due west of the College buildings, was judged to combine various advantages of situation and seclusion. It is on a hill about 150 feet above the level of high tide of the Potomac river, which runs due east, at a distance of almost half a mile. The slope on all sides, save to the north, is quite abrupt, and the view, especially to the southeast, is remarkably fine.

The plans for the buildings were made and the first instrument ordered in the year 1841; the excavations were begun in 1843, and, three years later, the first observations were made. The building is 60 feet long from east to west and 30 feet wide. The middle portion is 30 feet square, two stories in brick, surmounted by a third in framework, capped by a rotary dome 20 feet in diameter.

The east and west rooms, which contain the meridian instruments, have meridian openings 2 feet wide in the roofs, continued down the north and south walls to within 2 feet of the ground. In the west room is the transit instrument by Ertel & Son, of Munich, mounted in 1844. The objective is 4.5 inches aperture, with a focal length of 6.5 feet, and has four eye-pieces, giving powers from 80 to 200. There was also in this room a good sidereal clock, by Molyneux, of London.

In the east room, mounted on two very massive piers, is a 45-inch meridian-circle, made by Troughton & Simms, of London, in 1845. It is graduated on silver to 5-minute divisions, reading by four microscopes to fractions of a second, and has a lens of 4 inches aperture. This room also contained a fine Molyneux sidereal clock.

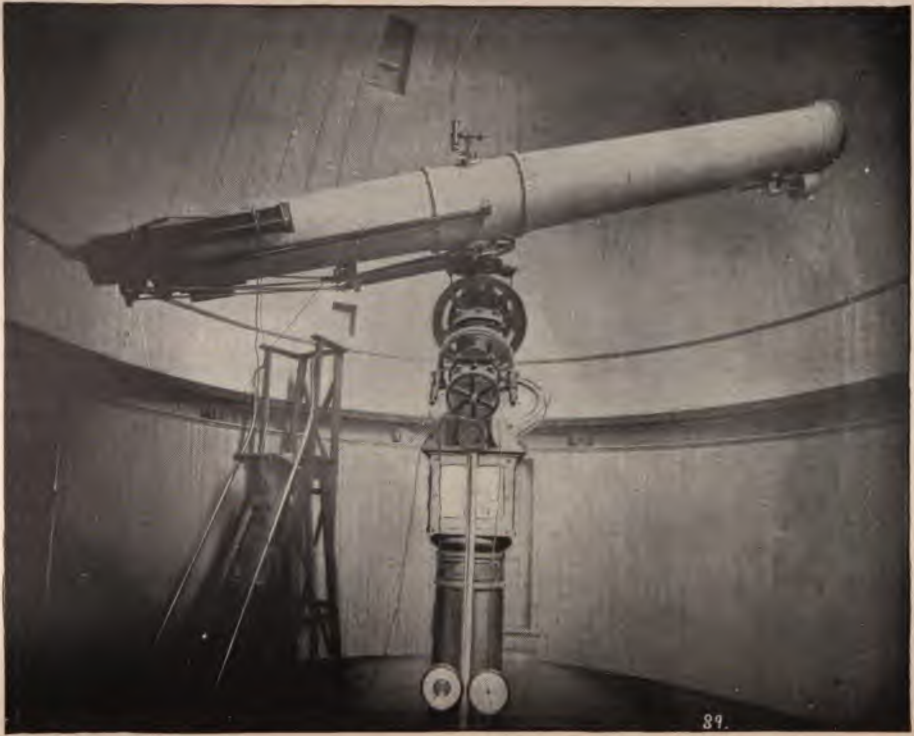
In the center of the main building, passing through the three floors, rises a pier of masonry 41 feet high, 11 feet square at the base, and 4 feet square at the top. It does not taper like a pyramid, but at every 7 feet in height it diminishes at once 5 inches all around; hence, its lateral surface is always vertical, but it has an offset in each room.

At its entrance to the dome-room, the pier is capped with freestone 10 inches thick, and on it was mounted in 1849 an equatorial telescope by TROUGHTON & SIMMS, of London. The object-glass is nearly 5 inches clear aperture and about 80 inches focal length, with eye-pieces affording powers from 25 to 400 diameters. The declination-circle is 20 inches in diameter, reading by 2 verniers to 5 seconds. The equatorial-circle is 16 inches in diameter, and reads to 1 second of time. The instrument was fitted with a driving-clock and a 1.5 inches finder of 13 inches focal length.

There were also two 3-inch refractors; a 10-inch reflecting-circle; a universal, or altitude and azimuth instrument, reading to 10 seconds, by ERTEL & SON, of Munich; a mean-time and a sidereal-time chronometer, and an arc of reflexion of 5°, with a radius of 22 inches, by TROUGHTON & SIMMS. A library was formed, consisting of some 500 volumes, and it at present contains the publications of nearly all the observatories and astronomical societies of the world.

The expenses of building and equipment were defrayed for the most part by donations from the Rev. THOMAS MEREDITH JENKINS, S. J., and the Rev. CHARLES H. STONESTREET, S. J., at that time Professors at Georgetown. The building of the observatory and the mounting of the instruments were superintended by the first Director, the Rev. JAMES CURLEY, S. J. He determined the geographical position of the observatory in 1846 —the longitude $+ 5^h\ 8^m\ 18.29^s$, by corresponding observations of moon-culminations at Georgetown and Greenwich; the latitude $38^\circ\ 54'\ 26''.2$, by upper and lower culminations of circumpolar stars.

The political disturbances in Europe brought several Italian Jesuit scientists to Georgetown, among whom were the three Jesuits, DE VICO, SECCHI, and SESTINI. The first mentioned was soon recalled to England, where he died November 15, 1848, at the age of forty-three. There is still preserved at Georgetown the gold medal which he received from the King of Denmark, for his discovery of six comets (I. 1844; II. 1847;



TWELVE-INCH EQUATORIAL OF GEORGETOWN COLLEGE.

I. V. VI. IX. 1846), while Director of the Observatory at the Roman College. He was a member of the Royal Astronomical Society of London.

Father SECCHI, then thirty years of age, taught physics for a year at Georgetown, and returned to Rome to enter on his career in physical astronomy; but his first interest in this study dates from the observations he made with Father CURLEY at Georgetown.

Father SESTINI began observations of star-colors in 1849, the manuscript of which is preserved in the library of the observatory. In 1850, he made drawings of Sun-spots from September 20th to November 6th, missing but 6 days out of 48. The drawings were lithographed, and together with a journal and preface, were published in the appendix of the Washington Astronomical Observations for 1847. A set of copies is still in the library of the observatory.

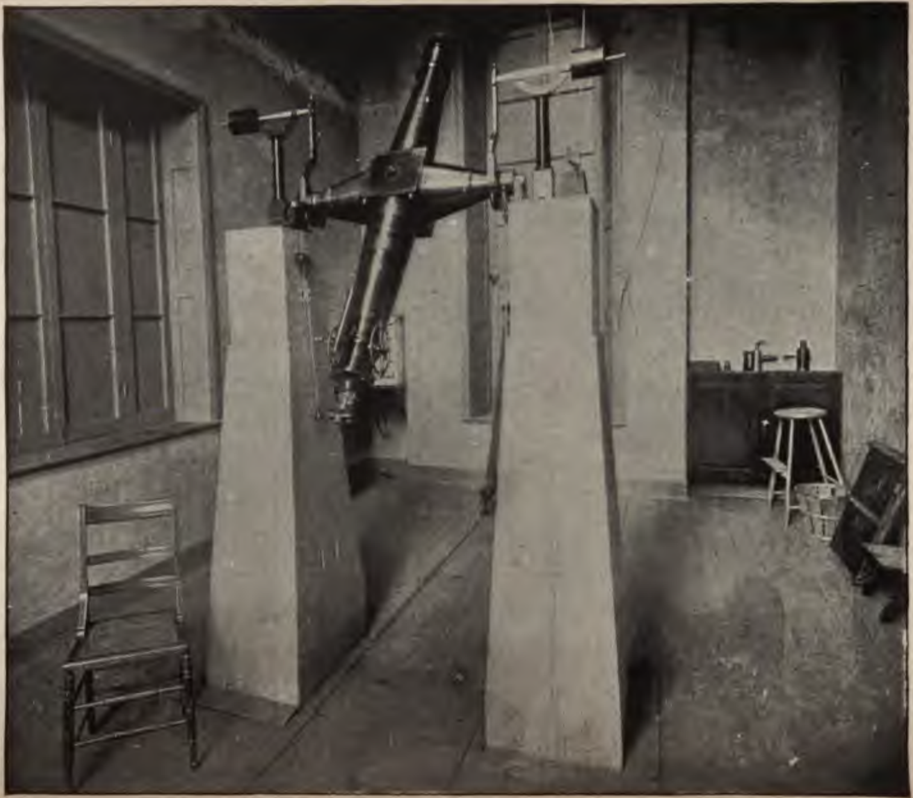
In 1852, a volume of 215 pages in quarto, containing a description of the observatory, with 8 plates and reduction-tables for time observations, was published and distributed by the Director. But the regular publication of astronomical work, nay, even that work itself, was found incompatible with the prosecution of the main design in founding the observatory, viz: the instruction of the students in the use of fine astronomical instruments. Hence, the first volume of the "Annals of Georgetown College Observatory," was also the last. Thus, for nearly half a century, Georgetown Observatory was little more than an adjunct to the physical laboratory and class-room, but in 1888, on the eve of the centennial celebration of the founding of the College, the Directors of the University decided to put a younger man at the head of affairs; to place a liberal allowance at his disposal, and to do everything necessary to bring into existence a practical working observatory; and so, the venerable Father CURLEY, at that time ninety-two years of age, resigned his honors and his responsibilities into the hands of the Rev. JOHN G. HAGEN, S. J., the present Director. Professor HAGEN is well known in mathematical circles as the author of a work entitled, "A Synopsis of Higher Mathematics," which is in course of publication in 4 quarto volumes. Two of these have already appeared and have been favorably received by the mathematical world.

The rehabilitation of the observatory was necessarily slow, for want of funds. The entire establishment and some of the instruments had suffered not a little from dampness and neglect, and a considerable sum of money had to be expended for repairs of the building, drying and heating the cellars, painting, etc. All the instruments were dismounted and thoroughly overhauled. The equatorial received a helioscope. One of the 3-inch glasses was mounted as a portable equatorial, and another as a comet-seeker. The clocks were carefully gone over and removed to the middle room of the first floor, where the temperature could be properly controlled. They were attached to the equatorial pier, enclosed in double glass cases and provided with the GARDNER electric spring contact. A new chronograph, by FAUTH & Co., of Washington, was placed between them.

A triple electric-wire system was run to a switchboard in the clock-room, one making connection with the U. S. Naval Observatory, another connecting the clocks and observing keys with the chronograph, and a third affording incandescent illumination for the field and the reading microscopes of the equatorial and meridian instruments. The arrangement of the switchboard is due to Dr. WILLIAM C. WINLOCK, at that time Assistant Observer at the U. S. Naval Observatory, and is similar to that in use at the observatories of Harvard College and Mount Hamilton, Cal. Two substantial brick piers, capped with freestone, were erected to the south of the main building, one in front of either wing, for use with collimators and portable instruments; they were provided with electrical connections for the chronograph, clocks, and incandescent lighting.

As a suitable field of work for the 5-inch equatorial, now in good condition, the Director chose *Stellar Photometry*, leaving all routine work, observations of planets, double stars, nebulæ, etc., to fully manned and better equipped establishments. The results have appeared on various occasions during the past six years in the "Astronomical Journal." The same instrument was afterwards devoted to a regular and systematic determination of the relative brightness of all the stars in the neighborhood of some of the most interesting objects in the sky.

These signs of awakened vitality soon aroused the interest of the friends of the observatory, and their zeal took the practical shape of donations, amounting in all to $20,000, part of which was destined for the construction of a 12-inch equatorial. For the reception of this new instrument, the dome had to be partly remodeled and elevated, and the 5-inch equatorial was installed



TRANSIT INSTRUMENT OF GEORGETOWN COLLEGE.

in a 12-foot dome, erected on the grounds a little to the southwest of the west transit-room.

Circumstances conspired at this juncture to focus the Director's attention on photographic meridian observations, and the ERTEL transit was thoroughly fitted up for the purpose, and intrusted to Professor G. A. FARGIS, S. J. The outcome of these investigations was dubbed the "Photochronograph." This device attached to the eye-end of the transit instrument and connected electrically with a sidereal clock, records automatically on a sensitive plate the exact time of the passage of a star across the meridian; and, in such fashion, that while it eliminates personal equation, it introduces no new instrumental error.

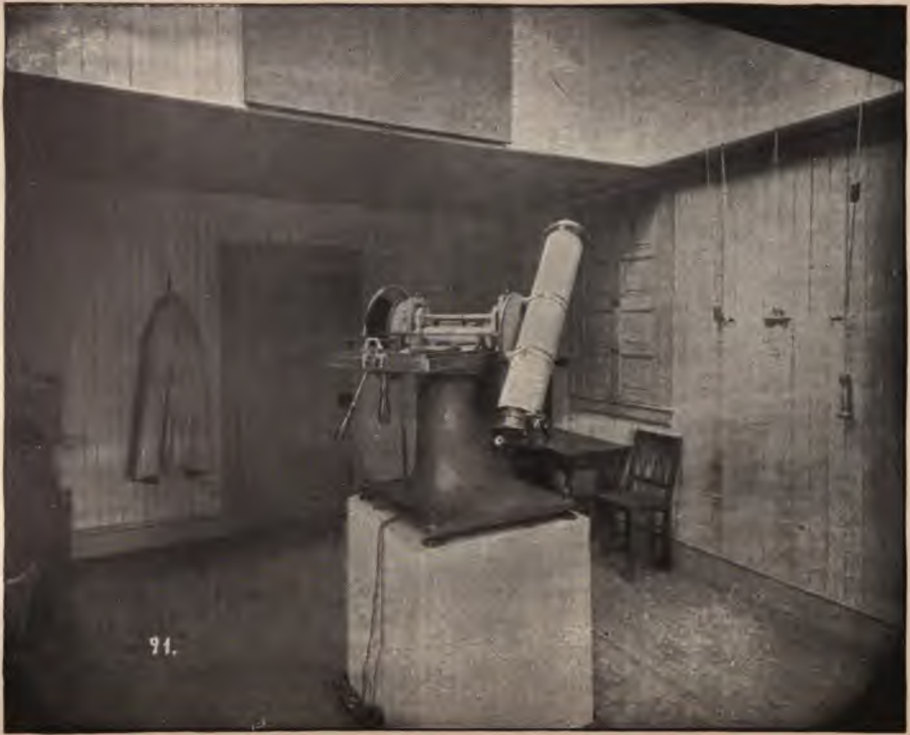
The photochronograph designed by Professor FARGIS, and constructed by Mr. G. N. SAEGMULLER, of Washington, was set to work October 3, 1890, and thenceforward, until June 29, 1892, —127 nights in all,—the method was rigorously tested. Over 3000 photographic transits were secured, and more than a quarter of a million micrometric measures of the plates made with a microscope designed for the purpose. The results, comprising some 1800 folio pages of manuscript, were confided to the care of Professor JOHN T. HEDRICK, S. J., who joined the observatory staff in June, 1891. The whole mass of material has been carefully studied, and the results are now in shape for the press, and will appear shortly in a separate publication. Thus, the scientific world will be enabled to pass competent judgment on the advantages and disadvantages of this new departure in astronomical work. A full description of the photochronograph and its practical working, with some preliminary results, was published and distributed in February, 1891.

It was the intention of the Director from the very start to study the laws of polar variation by means of photography. Various methods for the determination of latitudes and their periodic variations had been repeatedly pronounced highly desirable and quite feasible; but a practical method, embracing all the advantages of existing methods, and capable of putting the whole record graphically on the sensitive plate, had not hitherto been suggested. It was determined from the outset, that the spirit-level should be replaced by mercury, and early in 1891, the *floating* principle was adopted, but the plan remained incomplete until Professor FARGIS suggested the application of the photochronograph.

In August, 1891, the order was given for the "*Floating Zenith Telescope.*" It had a 6-inch photographic combination of lenses by BRASHEAR, of 35 inches focal length, with a specially constructed double-bar photochronograph; the whole roughly mounted on a float resting in a bath of mercury, and maintaining, in consequence, a constant level. In May, 1892, a complete and successful set of photographic latitude determinations, without the use of the spirit-level, were made and the results published and distributed as before. For the proper housing of this instrument, a frame building, 12 by 14 feet and 18 feet high, was erected to the east of the east transit-room, and was fitted with accessories, such as clocks, electric lights, etc.

Rev. JOSÉ ALGUÉ, S. J., the present Director of the observatory at Manila, Philippine Islands, and at this time engaged in special astronomical work at the Georgetown Observatory, encouraged by the success of the floating zenith telescope, undertook a series of experiments to test the merits of the *reflecting* principle. His efforts were crowned with success, and resulted in a new adaptation of the photochronograph, and the invention of a new instrument called the "*Reflecting Zenith Telescope.*" It consists of two photographic objectives, each of 4 inches aperture, placed at either end of a tube twice their focal length; the sensitive plate and disk-photochronograph being placed midway between the objectives, where the focal points meet. Thus, the light of one star of a latitude pair comes directly through one of the objectives to the sensitive plate; while the light of the other is first reflected from a suitably placed basin of mercury, through the second lens, to the same plate. The first successful observations were made in April, 1893, and a description of the instrument, its practical workings, and the preliminary results were published and distributed in June, 1893. This instrument was shortly afterwards dismounted and shipped to Manila, where it is now being used in connection with Georgetown Observatory, in studying the laws of polar variation.

These two methods eliminated the spirit-level, but others still were available. For instance, RÖMER, about two centuries ago, constructed an instrument, which he called the "Perpendiculum," and it was the intention of the Georgetown staff to utilize it as a "*Hanging Zenith Telescope,*" substituting a sensitive plate for the wire system at the eye-end. But the large outlay required for the careful construction of an instrument of this description,



FLOATING ZENITH TELESCOPE OF GEORGETOWN COLLEGE.

in order to secure results comparable with those of the instruments just described, caused the abandonment of the design.

Yet it was clearly necessary to test the visual and photographic methods of latitude determinations on more equal terms. Accordingly, in the early summer of 1893, a series of experiments was made with an ordinary zenith telescope of 3 inches aperture, in which the micrometer was replaced by a plate-holder and the usual latitude levels retained. The results were sufficiently satisfactory to warrant the construction of an instrument of this class, specially adapted to photography. The realization of the plans was intrusted to Mr. G. N. SAEGMULLER, of Washington. The completed instrument was mounted early in September, 1893, and the first latitude observations were made October 14, 1893. A full account was published and distributed in December, 1893. This "*Photographic Zenith Telescope*," furnished with a suitable photochronograph, was mounted on the pier built for the floating zenith telescope, which had to be laid aside until ampler accommodations could be secured. The 6-inch photographic lens of this latter instrument was utilized in the new one, which cost, notwithstanding, over $1,000. Regular series of observations are now in progress and the results will be made public as fast as material accumulates and the proper reductions can be made. It will be noticed, therefore, that the members of the staff of this observatory have successfully applied three new methods for the photographic determination of latitudes, each one exhibiting an important application of the photochronograph, which, in this case, may be said to have fairly covered the field.

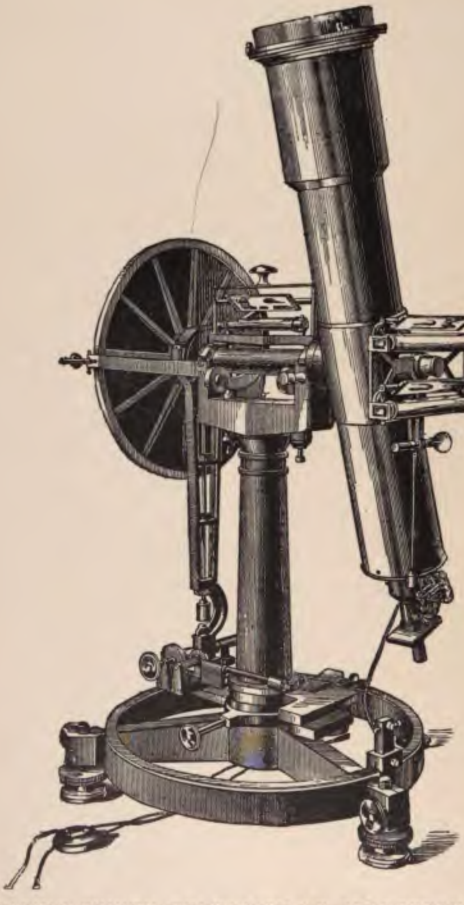
The 12-inch equatorial was not ready for work until March, 1893. The optical work is by Mr. JOHN CLACEY, and the mounting by Mr. G. N. SAEGMULLER, both of Washington. The lenses are of 12 inches clear aperture, with a focal length of about 15 feet. A third lens is used in connection with these, as a photographic corrector, which reduces the focal length by about 10 inches. They have given complete satisfaction, and the photographic combination, in particular, has successfully withstood some very severe tests. The mounting is first-class in every respect, and the motions are easy and accurate. It has a 4-inch finder, a fine driving-clock, reading-circles—coarse and fine,—with the clamps and slow motion screws for Right Ascension and Declination at the eye-end, and is furnished with a complete system of incandescent illumination. A very interesting series of observations was at once undertaken, and a new photographic method of studying double stars, planets and satellites, was successfully inaugurated. In this method, the photochronograph again plays the principal part, and, as appears from the measures under the micrometer microscope, the accuracy attained is greater than that reached in the visual method. An extended account of the method and preliminary results was published and distributed in January, 1894.

As it was impossible for the observatory staff to exhaust the whole photochronographic field by actual experiment, a sixth publication was issued, in which further applications of this instrument were suggested, and its bearing on the subject of personal equation thoroughly examined and criticised.

The six publications issued from the observatory during the years 1891–1894 have been collected into one volume under the title: "*The Photochronograph and its Applications.*" The next publication, almost ready for the press, gives a full account of the series of photographic transits previously mentioned. The study of these very satisfactory results has determined in no small degree the character of the future work of this observatory, and orders have already been given for the construction of a first-class photographic transit instrument, the first of its kind. The objective will be of 9 inches clear aperture and of extremely short focal length, and the mounting will be such as to be perfectly responsive to the severest demands on its stability and accuracy. It is confidently expected that it will be installed and in perfect working order before the end of 1896. It will occupy the place of the ERTEL transit, which will be disposed of, to make room for the more modern instrument. With it a fundamental catalogue of the Right Ascensions of all the stars within its grasp will be undertaken, and with it the instrumental equipment of the observatory may, at last, be considered complete.

The regular work of the 12-inch equatorial is, however, visual, and not photographic. It is with this instrument that the present Director extends and completes the photometric work carried on with the 5-inch equatorial during the past 5 years. Other celestial phenomena of exceptional interest, such as eclipses, star-showers, the new star in *Auriga*, etc., have been observed, and the results published in various astronomical journals.

The plan for the future work at the Georgetown College



PHOTOGRAPHIC ZENITH TELESCOPE OF GEORGETOWN COLLEGE.

Observatory, and the one now actually in operation, includes: (1) the photometric work with the 12-inch and 5-inch equatorials; (2) the determination of fundamental Right Ascensions with the new 9-inch photographic transit instrument; (3) the study of the variations of the polar axis, with the 6-inch photographic zenith telescope; (4) the determination of the positions of double stars and *Jupiter's* satellites, according to the photochronographic method, with the 12-inch equatorial. As an earnest of the faithfulness with which this programme is being carried out, it may be mentioned that the material for 9 new volumes is in preparation for publication.

THE STORM OF JANUARY 15, 1895, AT MOUNT HAMILTON.

By C. D. Perrine.

The storm which began on January 15th and lasted until the 23d was one of the severest in the history of the Observatory. In point of duration and intensity combined, it exceeded any previous ones, and the snowfall was about equal to the heavy one of February, 1890. The barometric pressure was the lowest on record, with but one exception — namely, that of February 23, 1891.

The barographic record of the recent storm is unusually interesting. The first indications of the approach of a storm were to be noticed on the night of January 10th, when the pressure, though still above normal, became unsteady. This unsteadiness increased during the next sixty hours, the pressure all this time remaining above the normal. At 2 P. M., on January 13th, the mercury began falling slowly but steadily, until 10:45 A.M., on the 15th, when it had reached 25.370 inches, a point at which very heavy storms are usually experienced. Here it began to fall with unusual rapidity until 10:30 P. M., when a series of very rapid and sharp variations set in, which culminated at 1:45 A.M., on the 16th, at 25.060 inches. The pressure fluctuated within about 0.10 inch of this point for a full day, and then rose slightly, and for the next three days ranged about

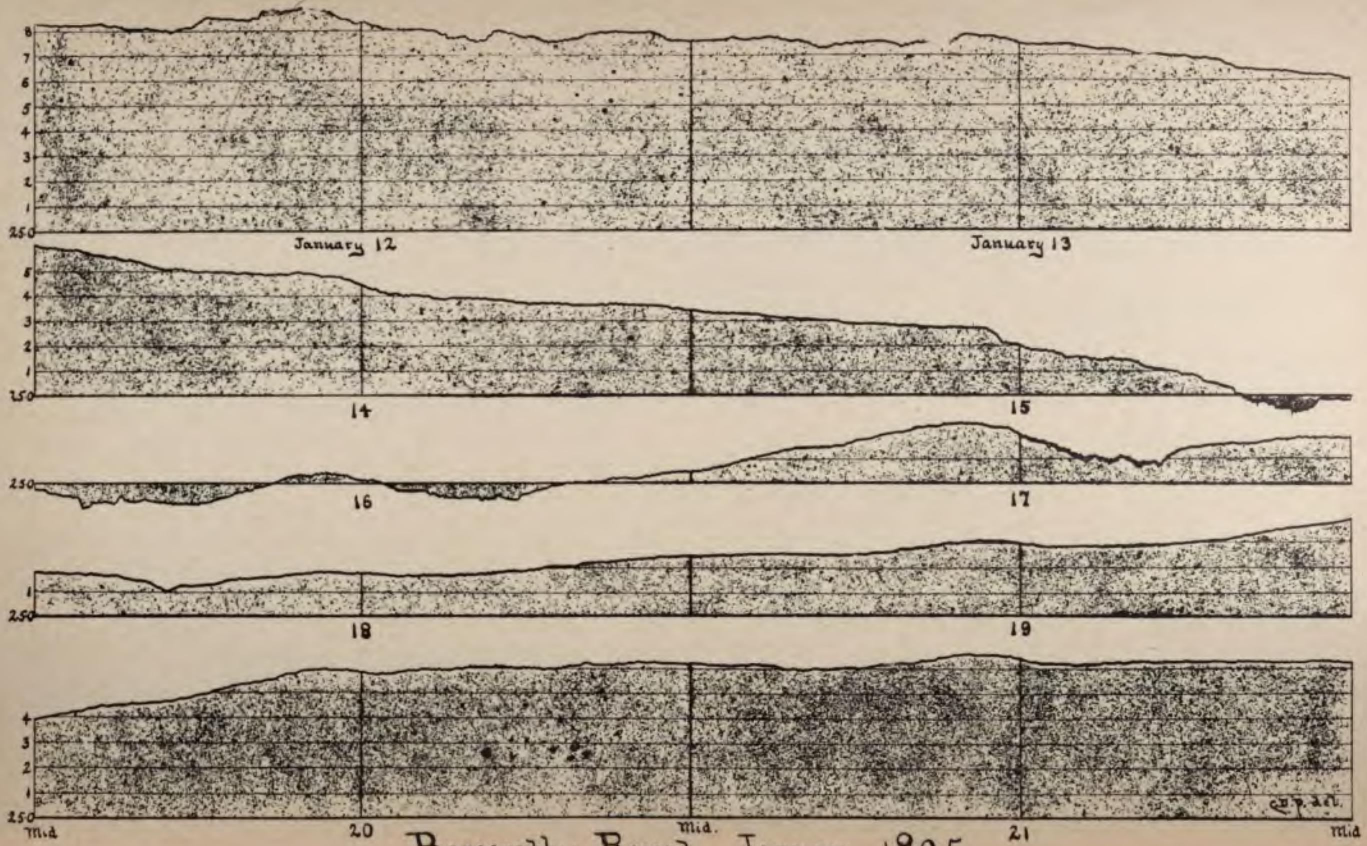
25.300 inches. From this, the pressure gradually recovered to the normal on the 23d.

The accompanying diagram shows the variations of pressure for the ten days beginning with January 12th, at midnight, as recorded by the Draper self-recording barometer of the LICK Observatory. The irregular heavy line at the top of the shading indicates the barometric pressure; the base line representing 25.00 inches, and each space $\frac{1}{10}$ inch. A systematic difference exists between this instrument and a standard mercurial barometer, the readings referred to above being from the latter. The wind was from the usual direction for the winter storms here, *i. e.*, south and southeast, and had been for some time previous. On the afternoon of the 22d the wind shifted to the north, and on the night of the 23d cleared off, after an interval of thirteen cloudy days. The wind velocity was greatest about 10 P. M. on the 15th. In attempting to read the dial, about 9:45, the anemometer was broken, so that the actual velocity is not known. From 5:04 P. M. until it was broken, about 9:45, there had been a total movement of 266.7 miles, or an average of over 57 miles per hour. At the time of the earlier reading, the velocity was not over 40 to 45 miles, and, as it did not increase much until about 8 P. M., the maximum velocity was, most probably, between 80 and 90 miles. The lowest temperature of the storm was but 5° below freezing, and usually ranged between 30° and 32° F.

As stated, the lowest barometer on record occurred on February 23, 1891, when, from 5 P. M. to 9:30 P. M., it fluctuated about 24.964 inches, but was below the normal for only 3½ days; while in the recent storm it remained below the normal for 9 days, and for 5½ days was below the point where the most of our heavy storms occur.

Snow began falling on the night of the 15th, and continued until the morning of the 20th, when there was an average of 4 feet or over on the ground, but drifted very heavily. Around the Observatory the drifts were 6 to 8 feet deep, and much deeper in other places.

On account of snow, the stages could not reach the Observatory between January 15th and February 1st. The drifts were still very deep near the summit, and would have been impassable for several weeks longer had they not been plowed open. The mails and small parcels of provisions were brought as far as



Barographic Record, January 1895

possible by the stages, which, for the first few days of the storm, was little more than half-way from Smith Creek. The remainder of the distance was made on horseback and on foot. For over a week the last half-mile had to be gone afoot.

The weight of snow and ice broke the telegraph and telephone wires frequently, but, as much of this damage occurred near the summit, it was repaired by those who went to meet the stages, and, by this means, the telephone was kept working for a portion, at least, of almost every day. The only other damage of any consequence was the breaking of some glass in the skylight over the main hall of the Observatory, and the breaking of some of the electric wires between buildings.

LICK OBSERVATORY, February 5, 1895.

LIST OF EARTHQUAKES IN CALIFORNIA FOR THE YEAR 1894.

COMPILED BY C. D. PERRINE.

The following list gives the dates and places of occurrence of earthquakes in California (including, also, a number outside of the State), compiled from observations at Mount Hamilton and reports received at the LICK Observatory, both by letter and newspaper. A number of disturbances have come under our notice which are not properly within our province, but which may possibly have escaped other compilers, and are, therefore, included.

The accounts of shocks in Nevada are, principally, from the Annual Report of the Nevada State Weather Service (Professor C. W. FRIEND, Director) for 1894.

This is a continuation of similar reports printed in Vol. II, p. 74; Vol. III, p. 247; Vol. V, p. 127, and Vol. VI, p. 41, of these *Publications*. A more complete account will be published as a bulletin by the United States Geological Survey. The dates are civil dates. The times are Pacific Standard (120th Meridian).

Roman numerals enclosed in parentheses indicate the intensity on the ROSSI-FOREL scale. The reports of the Lighthouse Board and of the Weather Bureau should be consulted in this connection.

There are, as yet, but few stations on the Pacific Coast equipped with instruments for the observation of earthquakes. Members of the Society, therefore, can assist materially in making these reports more complete and valuable by sending to the LICK Observatory descriptions of shocks which come to their notice.

LIST OF EARTHQUAKE SHOCKS, 1894.

January 14. Olympia, Tacoma, Wash., 3.25 A.M. Reported by Mr. FRED. G. PLUMMER, of Tacoma.
Vancouver and British Columbia generally.

January 24. Riverside, 3:50 A.M.

February 5. Keeler, 9:01 P.M.

February 7. San José, 2:09 A.M.

February 8. Los Angeles, 5:45 A.M. (and neighborhood).

February 15. Hawthorne, Nev., 9:01 P.M. (II).

March 3. Mount Hamilton, $4^h 42^m 50^s \pm$ P.M. (III). E. S. H.
$4^h 43^m 01^s$ P.M. W. W. C. and E. B. C.

May 7. Mount Hamilton, $11^h 56^m 7^s$ P.M. E. E. B.
$11^h 56^m 16^s \pm 10^s$ P.M. (III). W. W. C.
$10^h 52^m$ P.M., and $11^h 56^m 45^s$ P.M. R. H. T.

July 13. Pine Ridge (60 miles N.E. of Fresno), 8:50 P.M.

July 18. Ogden, Utah, 3:50 P.M.

July 29. San Bernardino, 9:15 P.M.; Los Angeles, 9:12 P.M.; Pasadena, 9:17 P.M.; Echo Mountain; Santa Monica, 9:11 P.M.; Santa Ana, 9:15 P.M.; Mojave, 9:12 P.M,; Ontario, 9:12 P.M.

August 3. Mount Hamilton, $11^h 50^m$ P.M. $\pm \frac{1}{2}^m$ (III to IV). E. S. H.

August 16. Pine Ridge. A recent earthquake (July 13?) is reported as damaging the dam across Stephenson Creek.

August 22. Lewers' Ranch, Nev., 4:28 A.M. (II).

September 30–October 1. Mount Hamilton. Some time between the evening of September 30 and the morning of October 1, a slight shock registered on the duplex seismograph, but was not felt by any one.

September 30. Eureka, 9:36 A.M. and 9:59 A.M.; Sisson.

October 16. New Hebrides Islands. An outbreak of volcanic eruptions and earthquakes began on October 16th, which lasted for a month, causing much loss of life and great damage to some of the islands. The center of the disturbance was on the island of Ambrim, at an old crater (Mount

Maryun), which became active, sending a stream of lava to the sea, and covering the island and sea for miles around with a dense layer of ashes.

October 23. San Diego, 3:03 P. M.; Coronado; Upper Otay Dam; Campo; National City; San Diego, 4:25 P.M.; Riverside, 3 P.M.; San Bernardino, 2:04 P.M.; Colton, 3 P.M.; Los Angeles, 3:05 P.M.

October 27. Los Angeles, 11 P.M.; San Diego, 11:05 P.M.

November 2. Mexico City, 4:17 P.M.

November 14. Gold Hill, Nevada, 2:02 P.M., and 6:58 P.M.; Lewers' Ranch, Nevada, 7:05 P.M. (I); Carson City, Nevada, 6:55 A.M. (I).

November 15. Carson City, Nevada, 11:07 P.M. (I), 11:25 P.M. (II), midnight (II); Gold Hill, Nevada, (II); Lewers' Ranch, Nevada, midnight (III); Virginia City, Nevada, 11:00 A.M. (II), 11:18 P.M. (II), 11:52 P.M. (II).

November 16–22. Virginia City, Nevada. "Over one hundred shocks of earthquake in this city within the week ending to-day (November 22)."

November 17. Campo, 5 P.M.

November 18. Nevada—Austin, 10 A. M. (II); Carson City, 2:38 A.M. (I), 2:40 A.M. (I), 2:49 A.M. (III), 5:15 A.M. (I), 5:33 A.M. (I), 6:22 A.M. (I); Gold Hill (II); Lewers' Ranch (I); Virginia City, 2:28 A.M. (II), 2:30 A.M. (I), 2:40 A.M. (IV), 5:24 A.M. (I), 6:18 A.M. (II).

November 21. Carson City, Nevada, in night (I); Tacoma, Wash., 6 P.M.; Mount Rainier. From 6:20 to 8 A.M., persons in Seattle and Tacoma report seeing smoke and steam issuing from the top of Mount Rainier. This phenomenon was reported at subsequent times. It was also reported that the shape of the peak had changed. The *Post-Intelligencer* of Seattle sent out an exploring party to investigate the matter. They were not able to reach the summit, but from one of the highest points reached, they report seeing, on December 24, steam jets issuing from the large crater, and a column of black smoke from the small crater. Immense avalanches were seen, and any changes of the contour of the mountain were ascribed to that cause.

November 24. Carson City, Nevada, 10:03 P.M. (II), 11:22 P.M. (III).

December 4. Carson City, Nevada, 9:39 P. M. (I); Lewers' Ranch, 9:40 P.M. (II).

December 18. Carson City, Nevada, 9:08 A.M. (II).

December 21. Gold Hill, Nevada, 2:20 A.M. (II).

December 23. "San Diego, Riverside, Pomona, and other points."

December 24. Boise, Idaho, 4 A.M., 6 A.M., 7:10 A.M.

December 28. Gold Hill, Nevada, 9:15 A.M. (I).

December 29. Gold Hill, Nevada, 4:30 A.M. (II), 5 P.M. (I).

December 30. City of Mexico, 10·53 P.M.

LATENT IMAGE OF EXPOSED DRY PLATES.

By PROFESSOR W. J. HUSSEY.

In No. 40 of these *Publications*, page 76, Mr. Perrine has given an account of the change which he has observed in the latent image of exposed dry plates. Since the permanency of the latent image is a matter of great practical importance to photographers and astronomers in all cases where the plates cannot be developed very soon after exposure, the following note may be of interest.

In May, 1891, I made a considerable number of contact positives at the observatory at Ann Arbor. I was unable to develop all of the exposures at the time. In April, 1892, some exposures for views were made that were not developed. These plates were brought to California in June, 1892, and in the following autumn one of the contact positives was developed. Nothing peculiar was noticed in the course of its development. This was at least sixteen months after its exposure. Last month, February, 1895, another of these contact positives was developed, and also one of the views. The former developed fairly well, showing that the image had not faded to any decided extent, if at all, in the course of the forty-five months that the image had lain latent. The view did not develop in a thoroughly satisfactory manner, but apparently from other causes than the fading of the image; probably largely on account of the poor quality of the lens used, and improper focusing.

The contact positives were made on Seed 26 plates, 6½ × 8½; the views, on Carbutt "Eclipse" plates, 5 × 7.

PLANETARY PHENOMENA FOR MAY AND JUNE, 1895.

By Professor Malcolm McNeill.

May.

Mercury passes superior conjunction with the Sun on May 4th, and becomes an evening star. It moves rapidly away from the Sun, out toward east elongation, which it reaches on June 4th. By the middle of the month it sets about an hour after sunset, and at the end of the month about an hour and three-quarters after. It attains a greater distance from the Sun at this elongation than it did at the preceding east elongation in February, owing to the circumstance that at the February elongation the planet was only two days from perihelion, whereas in the June elongation it is twenty-six days from perihelion. The last few days in May and the first days of June are, perhaps, the most favorable time of the year for seeing the planet.

Venus is an evening star, rather farther away from the Sun than it was in April. At the end of the month it remains above the horizon more than three hours after sunset. It is moving rapidly eastward among the stars, through the constellations *Taurus* and *Gemini*, and at the end of the month it is a few degrees south of *Castor and Pollux* (*Alpha* and *Beta Geminorum*). On the morning of May 24, during daylight in the United States, it passes about 2° north of *Jupiter*, and at the end of the month it is only 3° west and north of *Mars*, which it passes on June 5.

Mars is still an evening star, but is drawing nearer the Sun, and at the end of the month it sets before 11 o'clock. It is moving eastward among the stars, about one-third more than the Moon's diameter per day, about half as fast as *Venus*, and toward the close of the month is a few degrees south of *Castor and Pollux* and east of *Venus*. Its distance from the Earth is still increasing, and it grows a little fainter.

Jupiter is still an evening star, but its distance from the Sun is decreasing, and at the end of the month it sets at about half past nine. During the month it moves about 6° eastward, in the constellation *Gemini*.

Saturn rises before sunset, and is well above the horizon by the time the stars become visible in the evening. At the end of the month it is on the meridian at about half-past nine. During the month it moves about 2° westward, in the constellation *Virgo.* The rings are a trifle less open than in April, the ratio being about 3 to 10.

Uranus follows about an hour after *Saturn*, and about 7° south. It is in opposition on May 8. It moves westward about 1° during the month, and at the end of the month it is about 3° east and 1° south of the third magnitude star *Alpha Libræ.* It is just within the limit of naked-eye visibility on a clear moonless night.

Neptune is in *Taurus*, quite near the Sun, and comes to conjunction early in June.

JUNE, 1895.

On June 21, at about 9 A.M., Pacific time, the Sun reaches the solstice, and summer begins.

Mercury is an evening star throughout the month, and reaches its greatest eastern elongation, 23° 45′, on June 4 and from June 1 to June 11, remains above the horizon from $1^h\ 54^m$ to $1^h\ 39^m$ after sunset. This is a longer time by about 20^m than at the February elongation, and the conditions for visibility are therefore better than they were in February. The planet can probably be easily seen after sunset, in the evening twilight, until the middle of the month. At the February elongation, *Mercury* was less than two days from perihelion; at the present elongation, it is about eighteen days from aphelion, which comes on June 22. This accounts for the greater distance from the Sun. The relative motions of *Mercury* and *Venus* are quite interesting. At the beginning of the month *Mercury* is about 5° west of *Jupiter;* both are moving eastward; but *Mercury* is moving much the faster, and on June 8, in the morning, it is in conjunction with *Jupiter*, passing about 47′ north of the latter. Its eastward motion soon slackens, and on June 18 it begins to move westward, and on the evening of June 21 is again in conjunction with *Jupiter*, this time 2° 34′ south; so that it will make almost a complete circuit around *Jupiter* during the month. After the middle of the month it approaches the Sun very rapidly, and comes to inferior conjunction on the morning of July 1.

Venus is an evening star nearly out to eastern elongation, which it reaches on July 11. Its distance from the Sun will increase until that time: but, as will be seen from the tables, the time during which it remains above the horizon after sunset steadily diminishes throughout the month, being only about two and a half hours at the end. This is owing to its rapid diminution in declination — over 9° during the month. In addition to this southward motion, it is moving rapidly eastward, and on June 5, it passes less than one degree north of *Mars*. It is very close to the Moon on the evening of June 25, and it will be occulted in some places.

Mars is still an evening star, but the Sun is gradually overtaking it in its apparent eastward path. At the end of the month it remains above the horizon only two hours after sunset. During the month it moves about 18° eastward and 4° southward among the stars, moving from a point 2° east and 5° south of *Pollux* (*β Geminorum*) through *Cancer*, nearly to the constellation *Leo*. It reaches aphelion early in July, but at the end of June it lacks about 20,000,000 miles of its greatest distance from the Earth; it will reach this in September.

Jupiter is also an evening star, setting rather more than an hour before *Mars;* by the end of the month it is less than half an hour behind the Sun, and is too near that body to be easily seen. It comes to conjunction on the morning of July 10.

Saturn is in good position for observation. It retrogrades (moves westward) a little less than 1° toward the first magnitude star *Spica* (*α Virginis*), and is about 10° east of that star. The ratio of major to minor axis of the rings is about 28%, and the minor axis is about three-fifths the polar diameter of the planet.

Uranus is also in good position for observation. It crosses the meridian about an hour after *Saturn*, but, as it is 7° farther south, it sets only about half an hour later. It is in the constellation *Libra*, and during the month it moves 53′ westward and 14′ northward. It is about as bright as a sixth-magnitude star, not far from the limit of naked-eye visibility on a clear moonless night, and it may be found at the beginning of the month about 3° east and 1° south of the third-magnitude star *α Libræ*. During the month it moves toward the star, about one-third of its initial distance. *Spica*, X *Libræ*, and *β Scorpii* are nearly on a line, and *Saturn* is also near the same line, between the first two.

Neptune is in conjunction with the Sun on the morning of June 6, and becomes a morning star. It is too near the Sun to be seen, even with a good telescope.

EXPLANATION OF THE TABLES.

The phases of the Moon are given in Pacific Standard time. In the tables for Sun and planets, the second and third columns give the Right Ascension and Declination for Greenwich noon. The fifth column gives the local mean time for transit over the Greenwich meridian. To find the local mean time of transit for any other meridian, the time given in the table must be corrected by adding or subtracting the change per day, multiplied by the fraction whose numerator is the longitude from Greenwich in hours, and whose denominator is 24. This correction is seldom much more than 1^m. To find the standard time for the phenomenon, correct the local mean time by *adding* the difference between standard and local time if the place is west of the standard meridian, and *subtracting* if east. The same rules apply to the fourth and sixth columns, which give the local mean times of rising and setting for the meridian of Greenwich. They are roughly computed for Lat. 40°, with the noon Declination and time of meridian transit, and are intended as only a rough guide. They may be in error by a minute or two for the given latitude, and for latitudes differing much from 40° they may be several minutes out.

PHASES OF THE MOON, P. S. T.

		H. M.
First Quarter,	May 1,	7 44 P. M.
Full Moon,	May 8,	3 59 P. M.
Last Quarter,	May 16,	9 44 A. M.
New Moon,	May 24,	4 46 A. M.
First Quarter,	May 31,	12 48 A. M.

THE SUN.

1895.	R. A. H. M.	Declination. ° '	Rises. H. M.	Transits. H. M.	Sets. H. M.
May 1.	2 34	+ 15 5	5 2 A.M.	11 57 A.M.	6 52 P.M.
11.	3 12	+ 17 53	4 50	11 56	7 2
21.	3 52	+ 20 12	4 41	11 56	7 11
31.	4 32	+ 21 56	4 35	11 57	7 19

MERCURY.

1895.	R. A. H. M.	Declination. ° '	Rises. H. M.	Transits. H. M.	Sets. H. M.
May 1.	2 18	+ 13 7	4 53 A.M.	11 42 A.M.	6 31 P.M.
11.	3 43	+ 20 47	5 9	12 27 P.M.	7 45
21.	5 6	+ 25 3	5 36	1 11	8 46
31.	6 13	+ 25 26	6 1	1 38	9 5

VENUS.

1895.	R. A. H. M.	Declination. ° ′	Rises. H. M.	Transits. H. M.	Sets. H. M.
May 1.	5 0	+24 22	6 50 A.M.	2 23 P.M.	9 56 P.M.
11.	5 52	+25 25	6 58	2 35	10 12
21.	6 43	+25 16	7 11	2 47	10 23
31.	7 33	+24 5	7 27	2 58	10 29

MARS.

May 1.	6 25	+24 49	8 14 A.M.	3 48 P.M.	11 22 P.M.
11.	6 51	+24 23	8 2	3 35	11 8
21.	7 17	+23 41	7 52	3 22	10 52
31.	7 44	+22 43	7 43	3 9	10 45

JUPITER.

May 1.	6 14	+23 28	8 8 A.M.	3 37 P.M.	11 6 P.M.
11.	6 22	+23 26	7 37	3 6	10 35
21.	6 31	+23 21	7 7	2 35	10 3
31.	6 40	+23 15	6 37	2 5	9 33

SATURN.

May 1.	14 8	−10 6	6 2 P.M.	11 30 P.M.	4 58 A.M.
11.	14 6	−9 52	5 19	10 48	4 18
21.	14 3	−9 39	4 36	10 6	3 36
31.	14 1	−9 29	3 54	9 24	2 54

URANUS.

May 1.	15 3	−16 56	7 26 P.M.	12 29 A.M.	5 32 A.M.
11.	15 2	−16 49	6 40	11 44 P.M.	4 48
21.	15 0	−16 42	5 59	11 3	4 7
31.	14 59	−16 35	5 17	10 22	3 27

NEPTUNE.

May 1.	4 52	+21 6	6 54 A.M.	2 15 P.M.	9 34 P.M.
11.	4 54	+21 9	6 17	1 37	8 57
21.	4 55	+21 12	5 39	12 59	8 19
31.	4 57	+21 14	5 2	12 22	7 42

ECLIPSES OF *JUPITER'S* SATELLITES, P. S. T.

		H. M.			H. M.
I R.	May 1,	4 58 P.M.	I R.	May 14,	6 15 P.M.
I R.	5,	9 51	II R.	15,	10 10
I R.	7,	4 20	I R.	21,	8 10
II R.	8,	7 34	III R.	30,	8 13

PHASES OF THE MOON, P. S. T.

		H. M.
Full Moon,	June 7,	3 0 A. M.
Last Quarter,	June 15,	3 28 A. M.
New Moon,	June 22,	1 51 P. M.
First Quarter,	June 29,	6 1 A. M.

THE SUN.

1895.	R. A. H. M.	Declination. ° ′	Rises. H. M.	Transits. H. M.	Sets. H. M.
June 1.	4 36	+22 4	4 35 A.M.	11 58 A.M.	7 21 P.M.
11.	5 18	+23 6	4 32	11 59	7 26
21.	5 59	+23 27	4 32	12 1 P.M.	7 30
July 1.	6 41	+23 8	4 36	12 4	7 32
MERCURY.					
June 1.	6 18	+25 18	5 57 A.M.	1 39 P.M.	9 15 P.M.
11.	6 55	+23 10	6 9	1 37	9 5
21.	7 1	+20 26	5 47	1 3	8 19
July 1.	6 40	+18 39	4 52	12 2	7 12
VENUS.					
June 1.	7 38	+23 55	7 28 A.M.	2 59 P.M.	10 30 P.M.
11.	8 25	+21 35	7 46	3 6	10 26
21.	9 9	+18 26	8 6	3 11	10 16
July 1.	9 49	+14 40	8 18	3 12	10 6
MARS.					
June 1.	7 46	+22 36	7 42 A.M.	3 7 P.M.	10 32 P.M.
11.	8 12	+21 21	7 34	2 54	10 14
21.	8 38	+19 52	7 30	2 40	9 50
July 1.	9 3	+18 10	7 20	2 25	9 30

Jupiter.

1895.	R. A. H. M.	Declination. ° ′	Rises. H. M.	Transits. H. M.	Sets. H. M.
June 1.	6 41	+23 14	6 34 A.M.	2 2 P.M.	9 30 P.M.
11.	6 50	+23 5	6 5	1 32	8 59
21.	7 0	+22 53	5 35	1 2	8 29
July 1.	7 9	+22 39	5 7	12 32	7 57

Saturn.

June 1.	14 1	− 9 29	3 48 P.M.	9 20 P.M.	2 52 A.M.
11.	13 59	− 9 22	3 7	8 39	2 11
21.	13 58	− 9 18	2 27	7 59	1 31
July 1.	13 57	− 9 18	1 47	7 19	12 51

Uranus.

June 1.	14 58	−16 35	5 13 P.M.	10 18 P.M.	3 23 A.M.
11.	14 57	−16 29	4 32	9 37	2 42
21.	14 56	−16 24	3 51	8 57	2 3
July 1.	14 55	−16 20	3 10	8 16	1 22

Neptune.

June 1.	4 57	+21 14	4 59 A.M.	0 18 P.M.	7 37 P.M.
11.	4 58	+21 17	4 17	11 36 A.M.	6 55
21.	5 0	+21 19	3 40	10 59	6 18
July 1.	5 2	+21 21	3 2	10 21	5 40

No eclipses of *Jupiter's* satellites are given this month, as *Jupiter* is too near the Sun for easy observation of such phenomena.

OBSERVATIONS OF THE TOTAL ECLIPSE OF THE MOON, MARCH 10, 1895.

By R. H. Tucker, Jr.

The times of beginning and end of the total eclipse were observed, using a pair of powerful field-glasses. The phenomena were as uncertain as usual in such cases, perhaps slightly confused in addition by thin clouds covering the Moon.

Time noted for beginning: $6^h\ 51^m\ 59^s$ P. S. T.
and end: 8 27 21

The face of the Moon beneath the shadow was slightly copper-colored preceding totality; strongly so during all of the total eclipse.

A darker patch of shadow extended from the northeast rim of the Moon, southwest to the edge of the shadow, before totality. During the total eclipse, this gradually shifted its position upon the disc, until it reached from the southwest rim of the Moon, towards the northeast, not quite to the northeast rim. This darker patch was not visible after totality, the shadow then being uniformly dusky, with no color.

OBSERVATIONS OF THE TOTAL ECLIPSE OF THE MOON ON MARCH 10, 1895.

By C. D. Perrine.

The following observations were made with the 12-inch equatorial of the Lick Observatory.

At $6^h\ 00^m\ 26^s$ P. S. T., the first glimpse of the Moon was obtained, through thick haze and smoke. The image was very much distorted, and it was not until $6^h\ 17^m$ that the outlines of the shadow became at all distinct. Haze was present during the entire evening, and sufficiently thick to interfere materially, especially with the occultations.

The Moon's disc was visible at all times, and quite conspicuous except for a brief time at mid-transit, and even then the outlines of the principal dark areas were visible to the naked eye. The region near the south pole was a pronounced copper color all through the total phase, while the region near the north pole was yellow, and only once or twice showed any coppery tinge. A very dark area, about half the width of the Moon in latitude, moved across the disc from east to west during totality.

The contacts observed were:

2d contact of shadow,	$6^h\ 51^m\ 55^s$ P. S. T.
3d " "	8 27 30
4th " "	9 25 20

The following are the times at which the shadow touched certain of the best defined objects in its advance:

$6^h\ 27^m\ 45^s$ P. S. T.,	E. wall of *Triesnecker.*
29 40	E. wall of *Plato.*
33 30	*Pliny* disappears.
40 45	E. wall of *Petavius.*
43 05	Shadow touches *Proclus.*
44 30	*Proclus* gone. Shadow on *Langrenus.*
45 15	Shadow touches *Mare Crisium.*
48 50	Shadow touches W. edge of *Mare Crisium.*

The receding shadow was observed crossing the following objects:

$8^h\ 33^m\ 43^s$ P. S. T.,	*Aristarchus* reappears.
37 18	*Kepler* reappears.
39 00	W. wall of *Gassendi* reappears.
42 40	W. cape of *Sinus Iridum* reappears.
46 12	W. wall of *Copernicus* reappears.
46 58	E. wall of *Plato* reappears.
48 38	W. wall of *Plato* reappears.
49 10	*Pico* reappears.
49 36	E. wall of *Tycho* reappears.
51 20	W. wall of *Tycho* reappears.
52 26	W. wall of *Archimides* reappears.
59 22	E. wall of *Triesnecker* reappears.
9 00 00	W. wall of *Triesnecker* reappears.
02 14	*Menelaus* reappears.
09 55	*Vitruvius* reappears.
15 53	*Proclus* reappears.
18 30	*Messier* (W. crater) reappears.
21 10	*Auzout* reappears.

OCCULTATIONS.

Mag.	Star.	P. S. T. of Disappearance.
9.5	BD + 3°, 2516	$7^h\ 12^m\ 44^s.0$
7.2	BD + 3°, 2519	7 42 55.0

LICK OBSERVATORY, March 15, 1895.

OBSERVATIONS OF THE TOTAL ECLIPSE OF THE MOON, MARCH 10, 1895.

BY ALLEN L. COLTON.

The lunar eclipse of 1895, March 10, was observed by me at Professor HOLDEN'S request, using a small portable telescope, fitted with a terrestrial eye-piece. The sky was very hazy, and the edge of the shadow ill-defined, so that I do not consider the observations of high accuracy. My efforts were directed to recording the times of transit of the edge of the shadow over recognized objects on the Moon's surface. Under the conditions it did not seem practicable, usually, to record the time more closely than to the nearest half-minute.

	P. S. T.
Before totality:	
1st edge *Mare Crisium*,	$6^h\ 44\frac{1}{2}^m$
2d " " "	6 49
Total,	6 52
End of totality,	8 27
After totality:	
Middle of *Grimaldi*,	8 29½
Aristarchus,	8 34
Kepler,	8 38
2d edge *Mare Humorum*,	8 41½
Cape Laplace,	8 43
Copernicus,	8 46¼
Plato,	8 48½
Tycho,	8 50
1st edge *Mare Serenitatis*,	8 57½
Manilius,	9 00½
Middle of bright streak across *Mare Serenitatis*,	9 03½
2d edge *Mare Serenitatis*,	9 08
Shadow passes off Moon's disc,	9 25½

THE KODAIKANAL SOLAR PHYSICS OBSERVATORY IN INDIA.

By C. MICHIE SMITH, Government Astronomer and Director.

Professor HOLDEN having asked me to give some account of the new observatory about to be built in South India, I gladly accede to his request. I must, however, explain at the outset that the plans are still in a somewhat sketchy state, and that the financial difficulties of the Indian Government render it necessary that the work should be commenced on a very modest scale.

The site chosen for the new observatory is near Kodaikanal, a popular Hill Station in the Palani Hills, in the Madura District of the Madras Presidency. The approximate geographical position is Lat. 10° 14′ N., Long. $5^h\ 10^m$ E.; height above sea-level, 7700 feet. A piece of land measuring about 89 acres has been set apart for the observatory; so that, even if the buildings in the station should extend much more than is at all probable, there is no risk of any houses being so placed as to interfere with the work of the observatory in any way. The hill selected for the observatory itself, though not the highest of the Palanis, is higher than any other near it, and a practically uninterrupted view of the horizon is got in all directions. In selecting the site special attention was paid to the question of mist, since in all such stations there is always a tendency to the formation of dense clouds of mist when the hot moist air rises from the plains. In the east of Kodaikanal the hills drop very rapidly to the plains, and at certain seasons of the year heavy clouds of mist roll up every afternoon; but the site of the observatory lies some two or three miles west of these cliffs, and, so far as I have been able to ascertain, the mist bank seldom reaches so far. I have spent many hours on the hilltop when the mist could be seen covering the whole station to the east, while only an occasional thin wisp drifted over where I was. Misty days and nights will doubtless be experienced at certain seasons, but, so far as statistics are available, the proportion of clear days and nights will be very large.

As regards meteorological conditions, the information available is not so full as might be desired, but it is sufficient to show that the site chosen compares favorably with any other which has been suggested in India. At one time Simla was proposed as a suitable place for an observatory, and at certain seasons of the year probably no better site could be found. At other seasons, however, the air is so full of dust rising from the heated plains that no observations of any value could be made. When the question of selecting a site for the observatory came up some three years ago, it was agreed that the choice practically lay between the Nilgiris and the Palanis. The best place on each was chosen (Kotagiri and Kodaikanal), and meteorological observations were carried on at each for a year. A discussion of the results by Mr. J. ELIOT, Meteorological Reporter to the Government of India, and myself showed clearly that Kodaikanal was to be preferred. A few of the actual statistics collected for Kodaikanal may be of interest:

The mean daily temperature varied from 54°.1 F. in December to 62°.2 in May; the mean for the year was 58°.5. The mean daily range varied from 11°.5 F. in August to 16°.8 in February.

The mean humidity varied from 47 per cent. in March to 83 per cent. in August; the mean for the year being 72 per cent. The actual number of days on which 0.01 inch of rain, and upwards, fell was 155, distributed through the 12 months thus: 4, 5, 3, 16, 19, 19, 21, 24, 8, 21, 7, 8. The total rainfall was 47.53 inches; but the average over a number of years for a station a mile and a half distant, and nearer the edge of the cliffs, is 61 inches.

There were 2056 hours of bright sunshine throughout the year, and a careful analysis of the records shows that the mornings and forenoons are usually clear, the afternoons frequently cloudy; but the clouds tend to clear away again before sunset. Of the state of the sky during the night, there is not much trustworthy information; but my own experience during a number of short visits is that a night which remains cloudy throughout is very rare, and that a large proportion of the nights are brilliantly clear. On the whole, the climate is a magnificent one, combining many of the advantages of tropical and temperate regions.

On two occasions I have made a series of astronomical observations at Kodaikanal—once in June and the other tim in February,—and both times with the most favorable resul On the second occasion the observations were designed t pare the relative merits of Madras, Kodaikanal, and Kotagiri for astronomical work, and the result left no doubt that Kodaikanal was far superior in every respect. It is not necessary here to go into details; but I may say that, as regards solar observations, both telescopic and spectroscopic, excellent definition could be obtained up to from 10:30 to 11 A.M., almost every day, and on several days good observations were also made in the afternoons. As regards night work, the most striking features were the wonderful brightness of nebulæ, and the sharpness of the images of the planets, even under high magnifying powers. In observing *Saturn*, for instance, even far from the zenith, a power of 360 could be used with advantage on a telescope of 3.7 inches aperture. In observing stellar spectra the clearness of the lines and the absence of "flickering" were very striking features to one who had made most of his observations from near the sea-level. Many other tests were made, but the advantages of high-level over low-level observatories are now so fully admitted that it is needless to detail them.

At first it is the intention that the work in the new observatory shall be mainly directed towards solar physics, and the proposed equipment consists chiefly of instruments already in India. These are two photoheliographs of the KEW pattern, with 4-inch and 6½-inch objectives, giving solar pictures of 8 inches and 12 inches diameter, at present at Dehra Dûn; a 6-inch COOKE equatorial, with a powerful, but somewhat obsolete, form of prism spectroscope for solar work, and the necessary minor instruments. In addition to these, there will probably be a 6-inch photographic lens of 36 inches focal length, mounted with the LEREBOURS and SECRETAN equatorial of the Madras Observatory as a finder, a small spectroscope, with a ROWLAND grating fitted for photography, and the zodiacal light spectroscope made for me by HILGER some years ago. Later, I hope that a large equatorial will be added, but for that we may have to wait for some time.

In addition to astronomical work proper, it is proposed to carry on actinometric and meteorological observations, and, in connection with the latter, it is probable that a low-level meteorological station will be started on the plains, some 6500 feet below, and at a horizontal distance of only 4 or 5 miles. The final designs for the buildings have not yet been prepared, but the observatory will probably be built in the form of a cross, of which the longer arms will lie east and west, with an equatorial dome at the east, and a transit-room at the west extremity. The north and south arms will also terminate in domes for one of the photoheliographs and the photographic equatorial. For the spectroscopic work, probably, a heliostat will be used in connection with a fixed telescope, the axis of which is pointed to the pole. The astronomer's house is to be built a little below the observatory, so as to be sheltered from the strong winds on the hilltop, but will be close at hand, while houses for two or three assistants will be built somewhat farther off.

The staff as at present proposed will consist of the director, —who will also have charge of the Madras Observatory,—three assistants, a clerk, a mechanic, and the necessary servants. The headquarters of the director will be at Kodaikanal, and there will be an assistant superintendent and two assistants at Madras to carry on the time service and the meteorological observations. Two other assistants, whose main work will be computing, will probably be stationed at Madras so long as the publication of the arrears of old observations is going on.

MADRAS OBSERVATORY, 19th February, 1895.

LATEST NEWS FROM *MARS.*

[From the Boston *Commonwealth.*]

By EDWARD E. HALE.

"Mr. LOWELL'S four lectures on the planet *Mars* were heard by crowded audiences of people who filled every seat and all the standing-room in Huntington Hall. For once, we got the very latest advices from that planet. The observatory in Flagstaff, as our readers know, was established by Mr. LOWELL himself, and the position of *Mars* in the last summer gave him opportunity to make such observations as have never been made before, and to reveal to us what are marvels indeed. The result, as our readers know, is the firm conviction in his mind that intelligent beings occupy the planet *Mars*, who know how to work in the common good, who have contrived public works of vastly larger extent than we of the Earth have dreamed of, and have carried out their contrivances with a precision and strength wholly unknown in mundane affairs.

It is impossible in print to describe the charm of Mr. LOWELL's lectures. His humor, his ready wit, his complete knowledge of the subject with which he deals are such as one has no right to expect in the same public speaker. The most serious considerations are made interesting by analogies with affairs with which we are familiar and in which we are at ease. Everybody knows how light his pen is when he writes of his travels; and his ease as a public speaker and the readiness with which he takes his audience into his confidence give an additional charm to the lectures as he reads, or rather as he delivers, them.

There are not more than twenty people in this Earth who have seen what he has seen. Even some of the great observatories of the world are so situated that they have not noted the marvels which the Flagstaff observatory has revealed to us. But truth is truth, and it matters but little whether at this moment it have twenty apostles or two thousand. It is certain that the revelations which the Flagstaff observatory has made from its signal station to the world are revelations which will be accepted.

It was Mr. LOWELL's good fortune to reveal the relations of what he calls so well the "oases" with which the great canals of *Mars* communicate. These "junctions," shall we say, where two, three, four, or even seven, canals meet each other, seem to be the fortunate spots on the surface of *Mars* where one supposes that the inhabitants live in luxury, which they have secured for themselves by the diligent work, perhaps, of ages upon ages in the past. That is to say, an "oasis" (and of the oases one dares not say how many there are—they are to be counted now by hundreds) is a circular or oval spot, perhaps of 150 miles in diameter, of living green. Its green is so dense and dark that when we are 40,000,000 miles from it, its rich verdure may still be made out, if we have an air as clear as they have at Flagstaff. The readers of the *Commonwealth* must not regret that this green fades away in its season. They must remember that Boston Common to-day does not present, even to their own eyes, the same aspect with which they regarded it in July or in August. It cannot be doubted that in the period of vegetation these strong-minded and strong-limbed men have been able to lay up, perhaps the barrels of flour, perhaps the bales of manioc, perhaps the bananas or oranges, with which in the long winter of *Mars* they shall make life tolerable and even luxurious.

Mr. LOWELL, with great humor, but with absolutely accurate mathematics, showed to his hearers how large and tall and strong the Martian people might be. The attraction of gravitation is only one-third what we have here. The mathematical reader will see at once, if he be an anatomist as well, that there is no reason why the men should not be 19 feet tall, and why the Venus of Milo of *Mars* should not be 16 or 17 feet high. The physical power of this man is as great in proportion; his memory of the past may be more accurate, as it would seem that his foresight for the future is more sweeping. So it is that a population quite as dense, we may believe, as the population of this world, a population which has not spent, apparently, most of its history in mutual throat-cutting and constant quarreling, has achieved the marvels of irrigation and vegetation which we see upon the planet *Mars* to-day."—Reprinted from the *Scientific American*, March 2, 1895.*

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* The foregoing report, by the Reverend E. E. HALE, of a course of lectures lately delivered by Mr. PERCIVAL LOWELL, Director of the LOWELL Observatory in Arizona, may, apparently, be taken as a semi-official account of the conclusions reached by Mr. LOWELL from his observations of 1894. Before accepting as proved "the marvels of irrigation and vegetation which we see on the planet *Mars* to-day," etc., it would seem that observations ought to be continued for more than a single season, so as to make it certain that these are, in fact, marvels of vegetation which are seen. Something is seen, no doubt, but I may say that nothing has been observed at the LICK Observatory during the years 1888–1895, so far as I know, which goes to confirm the very positive and striking conclusions here described. It is a point to be noted that the conclusions reached by Mr. LOWELL at the end of his work, agree remarkably with the facts he set out to prove before his observatory was established at all. (See *Publications* A. S. P., Vol. VI (1894), page 162.) EDWARD S. HOLDEN.

NOTICES FROM THE LICK OBSERVATORY.

PREPARED BY MEMBERS OF THE STAFF.

A. A. A. S. MEETING, 1895.

At a special meeting of the Council, held on January 26, it was decided to postpone the proposed meeting in San Francisco. An invitation from Springfield, Mass., to hold the meeting of 1895 in that city was accepted. The date of the meeting was fixed as follows: Council meeting, Wednesday, August 28, at noon; general sessions, Thursday, August 29, at 10 A.M.

F. W. PUTNAM, Permanent Sec'y.

SALEM, MASS., Jan. 30, 1895.

STANDARD TIME IN THE AUSTRALASIAN COLONIES.

The following note has been contributed by General W. J. PALMER:

MELBOURNE, Jan. 31, 1895.

The Australasian colonies have decided to adopt the standard zone time from midnight to-night. By the new mode of reckoning, Victorian time will be advanced 20 minutes, thus making Melbourne, Sydney, and Brisbane time alike,— 10 hours ahead of Greenwich — while Adelaide will be 9 hours ahead, Perth 8, and Wellington 11.—*Reuter's Telegram.*

A WHITE RAINBOW.

On February 24, about 10:30 A.M., a white rainbow was visible for about five minutes. It faded away, and reappeared again about ten minutes later.

The clouds were breaking away after a storm of several days' duration, and at intervals the sun would pierce them, the canyons remaining filled with cloud. It was against such a mass of mist in the north canyon that this rainbow appeared. At no time were any prismatic colors seen. C. D. P.

LICK OBSERVATORY, February 24, 1895.

METEOR SEEN IN NEVADA, MARCH 2, 1895.

VIRGINIA (NEV.), March 2.—A meteor of unusual size and brilliancy flashed across the sky, from the western to the eastern horizon, at 5:15 o'clock this morning. Its course was slightly north of east, and during its passage, the town was illuminated with a glare more dazzling than sunlight.

A local observer, who had an uninterrupted view of the flight of the visitor, says it shot out of the western horizon, from behind Mount Davidson. Its appearance was heralded by a noise like the roar of an approaching tempest, which swelled into tones resembling those of distant thunder, as it swept over the town. When it reached the zenith, the light radiating from it was of blinding brilliancy, and its course was marked by a trail of fire. Its contact with the Earth was followed by an explosion, the report of which was heard two minutes afterward. The point of collision was apparently in the range of hills east of Fort Churchill, about 30 miles distant from here. When it struck the earth, the flying particles of matter appeared to cover an area of several square miles.

RENO (NEV.), March 2.—At 5:48 o'clock this morning, a large ball of fire became visible in the southwestern heavens, and exploded with terrific force.

Early risers report the meteor a most magnificent sight. An eye-witness said that his attention was first attracted by a rushing noise in the heavens. He glanced in the direction whence the noise came and saw a great ball of fire. The sight so startled him that he involuntarily dodged. He watched the ball of fire pass through the heavens, expecting to see it fall somewhere within the limits of the city. It passed out of sight in a southerly direction. In about one or two minutes thereafter, there was the rumbling sound of an explosion, and the windows and doors of the surrounding buildings rattled, and the ground under his feet shook.

There was talk of a searching party going out to endeavor to discover the landing-place of the meteor; but when those who saw it fall compared notes, it was ascertained that at least one or two minutes elapsed between its fall and the sound of the explosion. The sound of the explosion was so loud that many who were sleeping were aroused. They thought that the powder magazine had exploded.—S. F. *Chronicle*, March 3.

DEATH OF JOSEPH A. DONOHOE.

JOSEPH A. DONOHOE, a life member of the Astronomical Society of the Pacific and founder of its Comet-Medal, died in San Francisco on April 5th, 1895, at the age of 69 years. Mr. DONOHOE had been a resident of California since its early days (1850). Until 1861 he was engaged in mercantile business, and since that time he was the head of the DONOHOE-KELLY Banking Company of San Francisco. He took much interest in the establishment of the Astronomical Society and in the founding of the medal which bears his name, although he was too busy a man to have more than a literary interest in science. E. S. H.

THE STUDY OF ATMOSPHERIC CURRENTS BY THE AID OF LARGE TELESCOPES, AND THE EFFECT OF SUCH CURRENTS ON THE QUALITY OF THE SEEING.

Mr. A. E. DOUGLAS, astronomer in the LOWELL Observatory, Arizona, has printed in the *American Meteorological Journal*, Vol. II, p. 397, an article with the above title. It is a study of the air currents which are to be seen within the tubes of large telescopes, and which are such enemies to the best definition. All users of large telescopes are familiar with the phenomenon. Dr. HENRY DRAPER, somewhere about the year 1878, commenced a study of it; but nothing has been printed on the subject, I believe, until the article by Mr. DOUGLAS, except the paper by VENTOSA (*Amer. Meteor. Jour.*, Vol. 7, page 89), on a method of determining the direction of the wind by observations of the undulations at the margins of the discs of the heavenly bodies. The question is too special to be treated here, but attention is called to this interesting paper in order that those more especially concerned may consult it. Copies of the *Journal* may be obtained from GINN & Co., 7 Tremont Place, Boston, for thirty cents. E. S. H.

AN AUSTRALIAN ASTRONOMICAL ASSOCIATION.

"A branch of the British Astronomical Association was inaugurated at a meeting of local members of the parent association, in Sydney, N. S. W., during February, 1895. A thoughtful address was delivered by the president of the branch (Mr. JOHN TEBBUTT, F. R. A. S.), and a large number of nominations were received for membership. Mr. TEBBUTT'S address, which occupied about three-quarters of an hour in delivery, traversed pretty well all the ground which can be covered by amateur observers of the heavens, and included a number of hints to possessors of telescopes as to how they might employ them."

—*The Sydney Herald.*

THE OBSERVATORY OF THE VATICAN.

The *Cosmopolitan Magazine* for March, 1895, p. 599, contains an excellent article by Father J. A. ZAHM, on the observatory—or, rather, observatories—of the Vatican. The article is admirably illustrated with cuts made from photographs lately taken. The observatory staff consists of nine astronomers.

E. S. H.

THE CANALS OF *MARS*, BY MR. J. ORR.

The following paragraphs are copied from the *Journal* of the British Astronomical Association, Vol. V, 1895, p. 209:

"Mr. PETRIE read a paper by Mr. J. ORR, a member of the West of Scotland Branch, on 'The Nature of the "Canals" on *Mars*.' The paper, which had been read at Glasgow at the meeting of the Branch, was to show the almost absolute impossibility of the belief, which at one time somehow obtained popular currency, that the so-called canals were of an artificial character—the work of a supposed Martian race. By ruling grooves on a globe illuminated by a strong light. Mr. ORR calculated that the minimum breadth for visibility of the Martian canals must be about 33 miles. The length of an average canal, as measured on SCHIAPARELLI'S map, is about 2000 miles; and since on our terrestrial canals a minimum depth is required, to insure a constant supply of water at the center (diminished by leakage, evaporation, etc.), a depth of at least 70 feet would be required in the case of such a Martian canal as *Tartarus*. Even granted that the diminished force of gravity on *Mars* would render the work of excavating a ditch 70 feet deep equal to a terrestrial one of 26 feet, it was calculated that the canals would contain about 1,634,000 of our Suez Canals, and would require an army of 200,000,000 of men, working for 1000 of our years, for their construction. Assuming that the population varies with the surface, since the area of the earth is about 3½ times greater than that of *Mars*, we should get a Martian population of about 409,000,000. All the adult males, and a large number of the women, must, therefore, have engaged in the great work.

"The writer supposed the 'canals' to be great fissures caused by the cracking of the surface in contraction due to cooling, the planet having reached a considerably more advanced stage in its life than the Earth.

"A slide having been shown, representing the general canal system as given by SCHIAPARELLI, the President (Mr. E. W. MAUNDER, of the Greenwich Observatory,) said he hoped that Mr. ORR'S statistical, but, nevertheless, amusing and instructive, paper might prove one more nail in the coffin of a very absurd idea, which had certainly got most undue currency—namely, that the canals on *Mars* could possibly be the work of human agents. The mere fact that the whole of the resources of one of the greatest nations in Europe had failed to dig a little ditch some 26 miles long, and, comparatively speaking, only a few feet wide, might, he thought, convince us that the people on *Mars*, supposing there were any, could scarcely excavate 80,000 or 100,000 miles of canals, 40 miles wide."

CORRECTION TO HUSSEY'S LOG. TABLES.

Page 95: log. sin. 33° 44′, should be 9.74455 in place of 9.74555.

R. H. T.

THE ROSSI-FOREL SCALE OF EARTHQUAKE INTENSITY.

As a ready means of defining the intensity of a shock of earthquake from the ordinary descriptions of its effects, the ROSSI-FOREL scale will be found convenient, and is reprinted from *Archives des Sciences Physiques et Naturelles*, Geneva, February, 1884, Vol. XI, page 148.

In discussing the reports of shocks which occurred between 1850 and 1887, Professor HOLDEN was led to make some additions to this scale for observations in California. These additions are italicized, and are in quotation-marks, being expressions actually used by newspapers, etc., in describing shocks whose intensity was otherwise known.

I.

Microseismic shocks recorded by a single seismograph, or by seismographs of the same model, but not putting seismographs of different patterns in motion; reported by experienced observers only.

II.

Shock recorded by several seismographs of different patterns; reported by a small number of persons who are at rest. "*A very light shock.*"

III.

Shock reported by a number of persons who are at rest; duration or direction noted. "*A shock;*" "*a light shock.*"

IV.

Shock reported by persons in motion; shaking of movable objects, doors, and windows; cracking of ceilings. "*Moderate;*" "*strong;*" "*sharp;*" (sometimes) "*light.*"

V.

Shock felt generally by every one; furniture shaken; some bells rung; some clocks stopped; some sleepers waked. "*Smart;*" "*strong;*" "*heavy;*" "*severe;*" "*sharp;*" "*quite violent.*"

VI.

General awakening of sleepers; general ringing of bells; swinging of chandeliers; stopping of clocks; visible swaying of trees; some persons run out of buildings; window-glass broken. "*Severe;*" "*very severe;*" "*violent.*"

VII.

Overturning of loose objects; fall of plaster; striking of church bells; general fright, without damage to buildings. "*Nausea felt;*" "*violent;*" "*very violent.*"

VIII.

Fall of chimneys; cracks in the walls of buildings.

IX.

Partial or total destruction of some buildings.

X.

Great disasters; overturning of rocks; fissures in the surface of the earth; mountain slides.

The following deductions relating to earthquake intensity are interesting in this connection, and are from *Bulletin* No. 95 of the U. S. Geological Survey, "Earthquakes in California in 1890 and 1891," by Professor HOLDEN:

If both the period, T, and the amplitude, *a*, of an earthquake wave are given, the maximum acceleration due to the impulse, which may be taken as a measure of the intensity or destructive effect of the shock, is given by the formula—

$$I = \frac{4\pi^2 a}{T^2}$$

in which the motion is assumed to be harmonic.

The relation between the intensity (I) of a shock, as determined by the formula above, and the numbers of the ROSSI-FOREL scale has been reduced from all available data up to 1888, and is given below in tabular form. It is, of course, a rough approximation only:

ROSSI-FOREL Scale.	Intensity, Millimeters, per second.	Difference.
I	20	. . .
II	40	20
III	60	20
IV	80	20
V	110	30
VI	150	40
VII	300	150
VIII	500	200
IX	1200	700

One of the objects of the earthquake observations on Mount Hamilton is to obtain data for correcting this table, so that the intensity of a shock, as defined mathematically by the formula

$$I = \frac{V^2}{a}$$

(where V is the maximum velocity of the vibrating particle), can be approximately inferred from the ordinary descriptions of its effects.

C. D. P.

TEACHING OF ASTRONOMY IN THE UNIVERSITY OF CALIFORNIA.

The attention lately given by the press to the question of how astronomy shall be taught in the University of California, is a striking sign of the interest taken in university matters, and as such is welcome to all university men. As several errors have crept into the published statements, it seems worth while to correct them here.

The annual cost of the LICK Observatory is not $30,000, but, on the average, less than $25,000. Of this cost, the State pays $20,000, and Mr. LICK'S Endowment Fund pays the remainder. The cost of Greenwich Observatory last year was over $56,000. HARVARD College Observatory, Paris, etc., cost as much as Greenwich, or more.

In June, 1887, a year before the Observatory was completed, a committee, consisting of Regents WALLACE, SWIFT and RODGERS, reported a plan for its organization. As Acting-President of the University, I attended the meetings of this committee, and the plan adopted was essentially the one recommended by myself. It provided that "it is the intention of the Regents to establish and maintain a College of Astronomy as one of the colleges in the University, such college to be called the LICK Astronomical Department of the University of California." This plan was unanimously adopted by the Regents on June 10, 1887. As Acting-President, I submitted to the Regents a further resolution providing that "the regular course of undergraduate instruction in astronomy in the University will be given in part in the Colleges of Science at Berkeley, and in part at the LICK Observatory." This resolution was adopted in March, 1888. It further provided for the admission of an indefinite number of graduate students at Mount Hamilton.

The Observatory was transferred to the University on June 1, 1888, and it was supposed that the institution would at once be made a College of Astronomy, as the Regents had expressly declared their intention in this regard. The new President of the University, Mr. DAVIS, did not take this view; and on his recommendation nothing was done in the matter of undergraduate instruction. The number of graduate students to be received at the Observatory was expressly limited to four. It was several months before permission was obtained to receive even one. It was decided that the astronomers at the LICK Observatory were not members of the Academic Senate (which includes all persons giving instruction in the University), and, furthermore, that residence at Mount Hamilton was not "residence at the University." Under these discouragements we did as well as we could. Since 1888 we have given instruction at the LICK Observatory to fifteen graduate and special students, several of them for two or more seasons. Of these, four were full professors of astronomy, and three were assistant professors, or instructors, in other institutions. We considered that in no way could we be of more use than in teaching the teachers. Our work of instruction is not confined to regular students. We have received about 40,000 visitors at Mount Hamilton since 1888. Many lectures have been given by the astronomers before general audiences, and before the Astronomical Society of the Pacific. Eight books have been published and distributed from the Observatory, and more than 750 communications have been made to scientific journals, magazines and newspapers. No observatory in the world has done anything like as much as this, during the period 1888–1895, to make its work generally known.

The present arrangements for instruction in astronomy at the University were adopted by the Regents after a full discussion of various plans. At that time I said that the Observatory could take entire charge of all instruction, undergraduate and otherwise, and that it stood entirely ready to do so; but that, in view of our limited staff (we have seven observers, while Greenwich, Paris, and HARVARD College Observatories have over forty, Rome, nine, and Rio Janeiro, sixteen), it would be wiser to keep our astronomers at their observations here, since the reputation of the Observatory among other establishments comes solely from these observations. These views were adopted by the Regents, and were, and are, approved by the President.

In my letter of February 27, 1895, which has been printed in various newspapers, I asked two things. First, that if any change was made by the Regents, it should be so made as to interfere as little as possible with our work here (since it requires an absence of about three days from Mount Hamilton to give a lecture of one hour at Berkeley); and second, that if any new programme was to be made for our work, we requested the privilege of helping to make it. These requests seem to be reasonable, and if they are, they will, no doubt, be granted by the Regents. Finally, I said what is now and ever has been true, that all the astronomers here were entirely ready to do their best to carry out any plans which the Regents should adopt.

If those interested in this matter will take note of these facts in connection with what has already been printed, nothing but good can come from this discussion. EDWARD S. HOLDEN.

THE LICK OBSERVATORY, March 18, 1895.

A LARGE REFLECTOR FOR THE LICK OBSERVATORY.

Mr. EDWARD CROSSLEY, F. R. A. S., of Halifax, England, proposes to present to the LICK Observatory the 3-foot reflecting telescope and its dome which now form part of his private observatory. The grateful thanks of the LICK Observatory are offered to him for this most generous and highly appreciated gift. EDWARD S. HOLDEN.

MOUNT HAMILTON, April 4, 1895.

A LARGE REFLECTOR FOR THE LICK OBSERVATORY.

The Director of the LICK Observatory yesterday received a telegram which announces that EDWARD CROSSLEY, Esq., lately Member of Parliament for Halifax, England, proposes to present to the LICK Observatory his great 3-foot reflecting telescope, with its dome and all its apparatus complete. Mr. CROSSLEY makes no conditions to his gift, except that his telescope when set up at Mount Hamilton shall be called the CROSSLEY Reflector, and that the expenses of transporting the instrument and dome from England to California shall be borne by Americans. The splendid instrument which Mr. CROSSLEY offers is well known to astronomers. It was constructed by Mr. A. A. COMMON, of London, and for the magnificent photographs made with it Mr. COMMON received the gold medal of the Royal Astronomical Society. It was then purchased by Mr. CROSSLEY, and set up in his private observatory at Halifax, England, along with other instruments. An experience of some years has shown Mr. CROSSLEY and his astronomer, Mr. GLEDHILL, that the climate of England is not good enough to do justice to this telescope and he therefore determined to present it to an observatory which was favorably situated, where it could be used to the fullest advantage. It is a great compliment to the LICK Observatory that Mr. CROSSLEY has selected it to receive his gift, and it is a practical recognition of the fact that California is the ideal climate for making astronomical observations, as has been fully shown by the experience of the past seven years. The addition of this great reflector to the equipment of the LICK Observatory, which already possesses the great 3-foot refractor, makes the instrumental outfit of Mount Hamilton decidedly superior to that of any observatory now existing.

The refractor is eminently suitable for certain kinds of work. There are other kinds in which the reflector possesses distinct advantages. As the LICK Observatory will soon have a great telescope of each kind established in a most favorable situation, it will be admirably fitted in the future for every kind of astronomical work. It may be mentioned that the original plan of the LICK Observatory contemplated the installation of a great reflector as well as a great refractor. It was found by the LICK Trustees that the funds left by Mr. LICK were not adequate to provide both these instruments, and the plan for making the reflector was reluctantly abandoned. The splendid gift of Mr. CROSSLEY comes to complete the equipment of the Observatory in the most satisfactory manner. The cost of dismounting the reflector and dome in England, of transporting them to California (only the more important parts of the framework of the dome will be required here), and of erecting the complete apparatus at Mount Hamilton must be raised by subscription in America before Mr. CROSSLEY'S generous offer can be definitely accepted.*
—San Jose *Mercury*, April 5, 1895.

SEPARATION OF HELIUM FROM A TERRESTRIAL SUBSTANCE.

LONDON, March 31.—The detection of the gas *argon* in the atmosphere is being followed by a rapid series of discoveries of great interest. Chemists have long known, theoretically, of the existence of another element, which has been called "*helium*," and which was revealed by the spectroscope in the Sun's rays. It was not known to exist in this planet.

Professor RAMSAY, a few days ago, in order to ascertain whether there was .something in the world with which argon would keep company, was examining the extremely rare earth found in Norway, known as *cleveite.* When this mineral was treated with weak sulphuric acid, it gave off a gas which has hitherto been regarded as nitrogen. The professor found by close examination that it was not nitrogen, but *argon;* and, moreover, there was associated with it another gas, which he found to be—to use his words—"a gas which has not yet been separated." He submitted it to Professor Crookes, and the result is to show that the gas thus found is *helium.*

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*Subscriptions to the fund for this purpose may be sent to the Director of the LICK Observatory, Mount Hamilton, California, U. S. A. They will be gratefully received and suitably acknowledged.

M. Berthelot, continuing his experiments in Paris, found in manipulating *argon* he developed at ordinary pressure a magnificent fluorescent substance, greenish yellow in color, and characterized by the spectrum as similar to that of the aurora borealis. From this he deduced that the northern lights are caused by a fluorescent matter derived from argon, and engendered through the influence of electrical emanations developed in the atmosphere.

Still another scientific triumph of the week is the liquefaction of hydrogen by Professor Olszewski, of Cracow. He finds that the lightest of all gases liquefies at 253° below zero.—S. F. *Chronicle*, April 1, 1895.

BIBLIOGRAPHY OF SPECTROSCOPY.

The *Report* of the British Association for the Advancement of Science for 1894 (page 163) contains a summary of the literature of spectroscopy which, with previous lists, brings the cataloguing up to the beginning of 1894. E. S. H.

DRAWINGS OF *MARS*, 1894.

The cut in this number of the *Publications* gives four diagrams of *Mars*, which show the south polar cap and protuberances from the terminator; and also a drawing of *Lacus Solis* made under very good conditions on October 3, and completed and verified October 11. E. S. H.

THE ASTRONOMICAL SOCIETY OF WALES.

A new society, with the above title, was formed in Cardiff, Wales, in January of 1895. It has already commenced the publication of a *Journal.* The best wishes of their colleagues in America are extended to the new society. E. S. H.

METEOR SEEN AT SEA.

The schooner Premier arrived from Grays Harbor yesterday morning. Captain HEEGAARD reports a peculiar experience on the way down. On Friday, the 1st inst., at 2 o'clock in the morning, while Mate NELSON was on watch, a big meteor shot out of the sky and buried itself in the ocean about 1000 yards away from the vessel, on the lee side.

The Premier was in latitude 43° 30′ north, and longitude 125° 40′ west. The sky, according to the mate, was suddenly illuminated, and the big mass of flaming metal came hissing along from west to east, looking like a blazing coal. The men watched its course in mortal terror until it disappeared with a loud explosion beneath the waves.—S. F. *Call*, March 3, 1895.

EARTHQUAKE SHOCKS FELT AT SEA OFF CAPE MENDOCINO.

The San Francisco *Chronicle* of March 8, 1895, gives an account of a severe earthquake shock experienced by two vessels some fifty miles off Cape Mendocino, in Long. 125° 20′, Lat. 40° (both approximate).

My *List of Recorded Earthquakes in California* (1887) contains several notices of shocks felt in this vicinity, as follows:

"At sea, 45 miles W. S. W. of Cape Mendocino;"
"At sea, 50 miles from Cape Mendocino;"
"At sea, Long. 126° 25′, Lat. 41° 55′;"
"At sea, Long. 125° 50′, Lat. 40° 24′;"
"At sea, Long. 125° 20′, Lat. 40°— (as above)."

A relief map of the ocean bed near Cape Mendocino, made by Professor GEORGE DAVIDSON and Mr. WINSTON, shows the coast to be very "steep-to"; and it further shows two submarine mountains in the neighborhood. The slipping of the earth at the junction of the steep submarine cliff with the (comparatively) flat ocean floor, may very well be the cause of some of these disturbances. It is also possible, at least, that they are connected with the two submarine elevations mentioned. More observations are needed to decide this question. It is a little remarkable that we have reports of shocks felt at sea in this vicinity and none, or few, at other points along the coast. E. S. H.

Minutes of the Meeting of the Board of Directors, held in the Rooms of the Society, March 30, 1895, at 7:30 P. M.

President **Campbell** presided. A quorum was present. The minutes of the last meeting were read and approved.

The following members were duly elected:

List of Members Elected March 30, 1895.

Mr. C. H. **Colburn**	Virginia City, Nevada.
Mr. Geo. W. **Edwardes**	533 South Orange St., Media, Pa.
Mr. H. Theodore **Henning**	809 Octavia Street, S. F., Cal.
Mr. O. H. **Ingram**	Eau Claire, Wisconsin.
Mr. E. B. **Ingram**	Eau Claire, Wisconsin.
Miss Agnes M. **Manning**	1215 Sutter Street, S. F., Cal.
Mr. J. S. **McWilliams**	Colorado, Mitchell Co., Texas.
Mr. Charles **Nelson**	6 California St., S. F., Cal.
Dr. Basil **Norris**, U. S. A.	Occidental Hotel, S. F., Cal.
Mr. D. P. **Simons**	Los Gatos, Cal.
Mr. Sommers N. **Smith**	Newport News, Virginia.
Mr. D. F. **Tillinghast**	315 Montgomery St., S. F., Cal.
Mr. Edward **Wesson**	1512 Park St., Alameda, Cal.
Mr. Ralph **Radcliffe-Whitehead**	Santa Barbara, Cal.

Miss Juliet **Porter**, of Worcester, and Mr. Wm. **Howat**, of Melbourne, were elected to life membership. Adjourned.

Minutes of the Annual Meeting of the Astronomical Society of the Pacific, held in the Lecture-Hall of the California Academy of Sciences, March, 30, 1895.

The meeting was called to order by President **Campbell**. The minutes of the last meeting were approved. The Secretary read the names of new members duly elected at the Directors' meeting.

The following papers were presented:

1. Address of the retiring President, by Professor W. W. **Campbell**.
2. The Georgetown College Observatory, by Rev. **Fargis**, S. J.
3. Earthquakes in California during 1894, by C. D. **Perrine**.
4. The Storm of January 15, 1894, at Mount Hamilton, by C. D. **Perrine**.

5, 6, 7. Reports of Observations of the Lunar Eclipse of March 10, 1895, by Messrs. **Tucker**, **Colton**, and **Perrine**.

8. Planetary Phenomena for May and June, 1895, by Professor M. **McNeill**.
9. Latent Images on Exposed Dry-Plates, by Professor W. J. **Hussey**.
10. The Moon (with lantern-slide illustrations), by Mr. A. L. **Colton**.

The Committee on Nominations reported a list of names proposed for election as Directors as follows: Messrs. BURCKHALTER, HOLDEN, HUSSEY, MOLERA, Miss O'HALLORAN, Messrs. PERRINE, PIERSON, SCHAEBERLE, STRINGHAM, VON GELDERN, ZIEL.

For Committee on Publication: Messrs. HOLDEN, CAMPBELL, BABCOCK.

Messrs. THAYER and ROSS were appointed as tellers. The polls were open from 8:15 to 9:00 P. M., and the persons above named were duly elected.

REPORT OF THE COMMITTEE ON THE COMET-MEDAL, SUBMITTED MARCH 30, 1895.

I.

This report relates to the calendar year 1894. The comets of 1894 have been:

Comet *a* (unexpected comet); discovered by Mr. W. F. DENNING, of Bristol, England, on March 26.

Comet *b* (unexpected comet); discovered by Mr. W. F. GALE, of Sydney, N. S. W., on April 1.

Comet *c* (TEMPEL'S periodic comet); discovered by Mr. W. H. FINLAY, Cape of Good Hope, on May 8.

Comet *d* (ENCKE'S periodic comet); discovered (visually) by Dr. V. CERULLI, Teramo, Italy, on November 1; also found by Dr. MAX WOLF, of Heidelberg, on his photographic plates of October 31.

Comet *e* (unexpected comet); discovered by Mr. EDWARD D. SWIFT, Mt. LOWE Observatory, California, on November 20.

The Comet-Medal has been awarded to the discoverers of Comets *a*, *b*, and *e*, in accordance with the regulations.

Respectfully submitted,
EDWARD S. HOLDEN,
J. M. SCHAEBERLE,
CHAS. BURCKHALTER,
Committee on the Comet-Medal.

II.

An unexpected comet was discovered by Professor J. M. SCHAEBERLE, of the LICK Observatory, on his photographic plates of the eclipse of April 16, 1893, and announced by him in August of that year. This comet was found on the eclipse negatives of the HARVARD College Observatory expedition, and of the British eclipse parties, during 1894.

The Comet-Medal has been awarded to Professor SCHAEBERLE for his discovery of the Eclipse Comet of April, 1893.

Respectfully submitted,
EDWARD S. HOLDEN,
CHAS. BURCKHALTER,
Committee on the Comet-Medal.

The Treasurer submitted his Annual Report as follows:

Annual Statement of the Receipts and Expenditures of the Astronomical Society of the Pacific for the Fiscal Year ending March 30, 1895.

GENERAL FUND.

Receipts.

Cash Balance April 1, 1894		$ 378 39
Received from dues	$1,629 87	
" " sale of publications	58 85	
" " sale of stationery	1 25	
" " advertisements	25 00	
" " Security Savings Bank (interest)	1 20	
" " Life Membership Fund (interest)	67 82	
" " " " " (transfer)	200 00	
	$1,983 99	
Less transfer to Life Membership Fund	100 00	1,883 99
		$2,262 38

Expenditures.

For publications	$1,078 40	
" general expenses	777 15	$1,855 55
Cash Balance March 30, 1895		406 83
		$2,262 38

LIFE MEMBERSHIP FUND.

Cash Balance April 1, 1894		$1,450 61	
Received from General Fund		100 00	
" " interest		67 82	
		$1,618 43	
Less Interest transferred to General Fund	$ 67 82		
" Cash " "	200 00	$267 82	
Cash Balance March 30, 1895			$1,350 61

DONOHOE COMET-MEDAL FUND.

Cash Balance April 1, 1894	$ 614 78	
Interest	29 83	
Cash Balance March 30, 1895		$ 644 61

ALEXANDER MONTGOMERY LIBRARY FUND.

Cash Balance April 1, 1894	$1,716 55	
Interest	85 23	
	$1,801 78	
Expended for binding	7 95	
Cash Balance March 30, 1895		$1,793 83

FUNDS.

General Fund. Balance on deposit with Grangers Bank,	$404 90	
" " Balance on deposit with Security Savings Bank	1 93	$ 406 83
Life Membership Fund. Balance on deposit with San Francisco Savings Union		1,350 61
Donohoe Comet-Medal Fund. Balance on deposit with San Francisco Savings Union		644 61
Alexander Montgomery Library Fund. Balance on deposit with San Francisco Savings Union	$ 870 10	
Alexander Montgomery Library Fund. Balance on deposit with German Savings and Loan Society	923 73	1,793 83
		$4,195 88

San Francisco, March 30, 1895. F. R. Ziel, *Treasurer*.

The Committee appointed to audit the Treasurer's accounts reported as follows, and the report was, on motion, accepted and adopted, and the Committee discharged:

To the President and Members of the Astronomical Society of the Pacific:

GENTLEMEN—Your Committee appointed to audit the accounts of the Treasurer for the fiscal year ending March 30, 1895, have made a careful examination and find same to be correct.

(Signed)
G. R. LUKENS, *Chairman,*
S. C. PASSAVANT,
OTTO VON GELDERN.

Professor CAMPBELL then read his Annual Address.

The following resolution was, on motion, adopted:

Resolved, That all the acts appearing in the minutes of the meetings of the Board of Directors of this Society, as having been done by said Board during the past fiscal year, are here now by this Society approved and confirmed.

Mr. A. L. COLTON, of LICK Observatory, delivered a lecture on *The Moon*, illustrated with seventy-five lantern slides. The lecture related to the folk-lore of the Moon, the Moon in art and literature, the history of lunar maps and photographs, descriptions of special features of the lunar surface, the theories of the origin of the craters, and the question of a lunar atmosphere.

The thanks of the Society were returned to the CALIFORNIA ACADEMY OF SCIENCES for the use of the lecture-hall. Adjourned.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD IN THE ROOMS OF THE SOCIETY, MARCH 30, 1895, AT 10:30 P. M.

The new Board of Directors was called to order by Mr. CAMPBELL. A quorum was present. The minutes of the last meeting were approved.

The business in hand being the election of officers for the ensuing year, the following officers,—having received a majority of the votes cast—were duly elected:

President: Mr. CHAS. BURCKHALTER.
First Vice-President: Mr. W. J. HUSSEY.
Second Vice-President: Mr. E. S. HOLDEN.
Third Vice-President: Mr. O. VON GELDERN.
Secretaries: Messrs. C. D. PERRINE and F. R. ZIEL.
Treasurer: Mr. F. R. ZIEL.
Committee on the Comet-Medal: Messrs. HOLDEN (*ex-officio*), SCHAEBERLE, HUSSEY.

The President was authorized to appoint the various Standing Committees of the Directors, and accordingly made the following selections:

Finance Committee: Messrs. VON GELDERN, PIERSON, STRINGHAM.
Library Committee: Mr. MOLERA, Miss O'HALLORAN, Mr. BABCOCK.

The Committee on Publications is composed of:
Messrs. HOLDEN, CAMPBELL, BABCOCK.

It was, on motion:

Resolved, That the Directors of the Astronomical Society of the Pacific extend to Professor CAMPBELL their thanks for his valuable services as President of the Society.

Adjourned.

OFFICERS OF THE SOCIETY.

CHAS. BURCKHALTER (CHABOT Observatory, Oakland),	*President*
W. J. HUSSEY (LELAND STANFORD Jr. University, Palo Alto, Cal.),	*Vice-Presidents*
E. S. HOLDEN (LICK Observatory)	
O. VON GELDERN (819 Market Street, S. F.),	
C. D. PERRINE (LICK Observatory),	*Secretary*
F. R. ZIEL (410 California Street, S. F.),	*Secretary and Treasurer*

Board of Directors—Messrs. BURCKHALTER, HOLDEN, HUSSEY, MOLERA, Miss O'HALLORAN, Messrs. PERRINE, PIERSON, SCHAEBERLE, STRINGHAM, VON GELDERN, ZIEL.

Finance Committee—Messrs. VON GELDERN, PIERSON, STRINGHAM.

Committee on Publication—Messrs. HOLDEN, CAMPBELL, BABCOCK.

Library Committee—Mr. MOLERA, Miss O'HALLORAN, Mr. BABCOCK.

Committee on the Comet-Medal—Messrs. HOLDEN (*ex-officio*), SCHAEBERLE, HUSSEY.

OFFICERS OF THE CHICAGO SECTION.

Executive Committee—RUTHVEN W. PIKE.

OFFICERS OF THE MEXICAN SECTION.

Executive Committee—CAMILO GONZALEZ, FRANCISCO RODRIGUEZ REY, AGUSTIN ARAGON.

NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the *calendar* year only Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our book-keeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific 819 Market Street, San Francisco.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 819 Market Street, San Francisco, who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed rests with the writers, and is not assumed by the Society itself.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend any or all of the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific" at the rooms of the Society, 819 Market Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

PUBLICATIONS ISSUED BI-MONTHLY.

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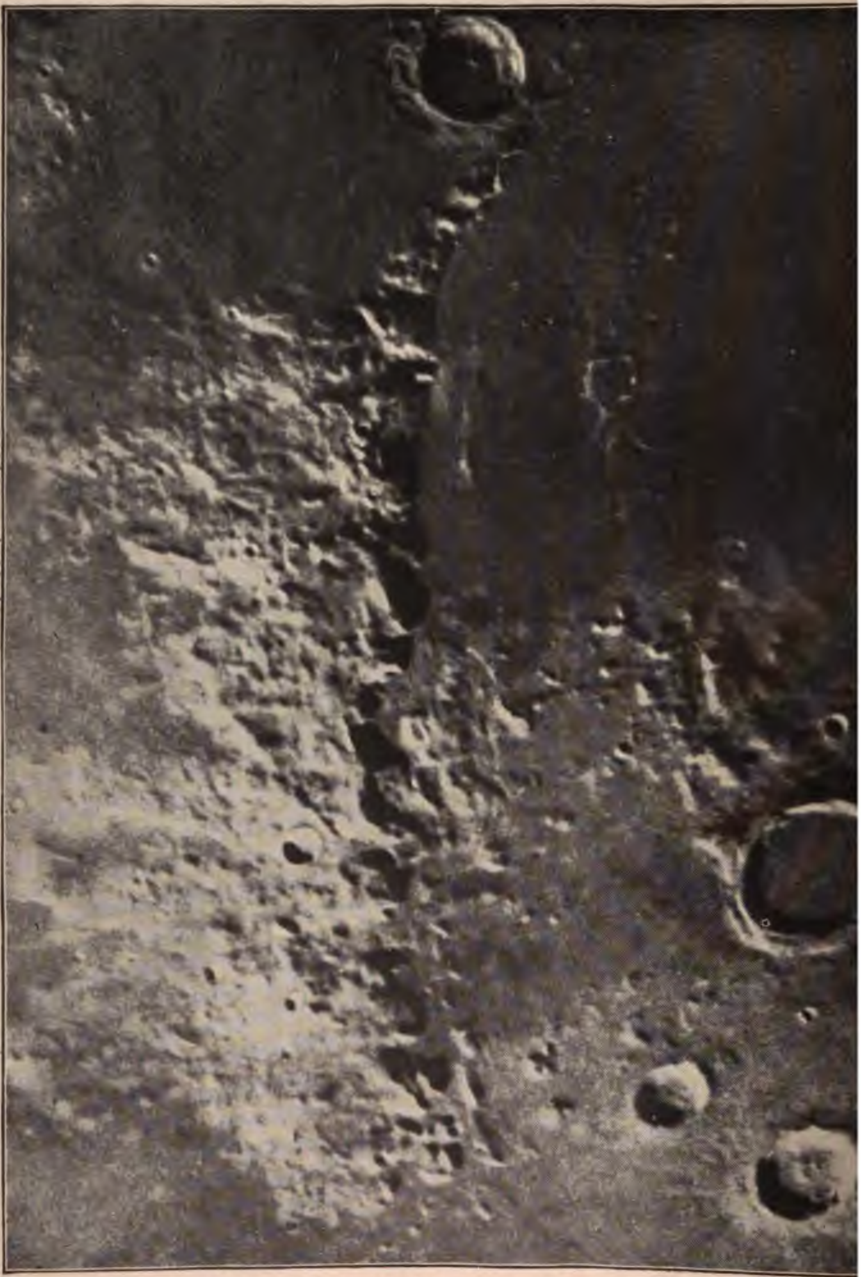

FROM A NEGATIVE TAKEN AT THE LICK OBSERVATORY, 1891, JULY 14.

PUBLICATIONS
OF THE
Astronomical Society of the Pacific.

VOL. VII. SAN FRANCISCO, CALIFORNIA, JUNE 1, 1895. NO. 42.

THE MOON AS SEEN BY A GEOLOGIST.*

[Abstract of a Paper by Professor EDWARD SUESS, entitled "Einige Bemerkungen ueber den Mond," printed in the *Sitzungsber. d. k. Akad. d. Wissenschaften in Wien*, February 1, 1895.]

Professor SUESS, the eminent Austrian geologist, communicated, on February 7th of this year, to the Imperial Academy of Sciences at Vienna, a paper on the Moon, considered from a geological standpoint. As a basis for his observations and conclusions, he used the famous lunar photographs of the LICK Observtory, enlarged by Professors WEINEK and PRINZ, and those made by Messrs. LOEWY and PUISEUX, at the Paris Observatory, which latter were also enlarged by Professor WEINEK. These photographs will be designated as L. W. (LICK-WEINEK), L. P. (LICK-PRINZ), and P. W. (Paris-WEINEK).

Professor SUESS starts with the reasonable hypothesis that the mineral matter covering the surface of the Moon is similar to the volcanic rocks of our Earth. If this be true, we perceive at once that, since our basaltic rocks—for example, the lavas of Hawaii—reach a specific gravity of 3.3, and the specific gravity of the mass of the Moon averages only 3.4, we can only assume the existence of our lighter, acid rocks on the surface of the Moon. LANDERER'S observations, comparing the angle of polarization of our acid terrestrial rocks with that of certain large, gray plains on the Moon—for example, *Mare Nectaris*, *Crisium*, *Fecunditatis* and *Tranquillitatis*—seem to confirm the correctness of this hypothesis. He found that the angle of polarization of these plains is 33° 17′, while terrestrial observations gave the following values, viz.: For ***basalt***, 31° 43′; ***trachite***, 32° 16′; ***andesite***, 32° 50′; ***vitroporphyry***, 33° 18′; ***hyalomelan***, 33° 39′; ***obsidian***, 33° 46′; and *ice*, 37° 20′.

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* Translated for the *Publications* A. S. P., by Mr. C. A. STETEFELDT. The footnotes of the original, which give bibliographic references, have usually been omitted here; a few have been added.

We have further to consider that the intensity of gravitation on the Moon is only one-sixth of that on Earth; hence, magmatic differentiation of lavas must be less on the Moon. Finally, there is no atmospheric pressure on the Moon to counteract explosions, and to check evaporation; and the great difference in temperature between day and night must have influenced the forms of solidification. All these conditions seem to have favored the intensity of volcanic action, and to have produced the bizarre forms of craters on the Moon.

In concluding the introduction of his paper, Professor SUESS pays a high tribute to our Professor DANA, who, nearly half a century ago, and before large photographs of the Moon existed, compared the volcanoes of Hawaii with those of the Moon, recognizing many peculiarities which they have in common.

The light reflected by different parts of the Moon presents great differences in intensity. Selenographers have attempted to express these degrees of intensity by a scale from 0° to 10°. According to NEISON, 0° refers to dark shadows; 1°, an almost black-gray, is rare; 2° and 3° appear, for example, in *Mare Crisium*, in parts of *M. Tranquillitatis*, and on the edge of *M. Serenitatis*. The majority of mountains and their interior plains range between 4° and 6°. Grades of 7° and above are comparatively rare, and do not correspond to large surfaces, but to spots, points, craters, etc.; only a few points reach 9°, and 10° is confined to the interior of *Aristarchus*. Neglecting details, it can be said that the plains are more or less dark, mountains lighter, and that the brightest portions are scattered and locally confined. It has been generally conceded that the latter are of most recent origin.

It would not be difficult to classify terrestrial volcanic products according to their colors. *Obsidian* and the great mass of basaltic rocks would come under 1° and 2°; medium gray tones would be represented by *trachytes* and *andesites*; while, from 7° upward, we would not have real lavas, white *rhyolites* excepted, but fumaroles and their by-products, pumice-stone and certain white volcanic ashes. Hence, rocks of the brightest colors, confined to limited areas, are of the latest origin on the Earth also.

How far are we allowed to compare these color-scales? As previously stated, we are not justified in assuming the existence of our heavy, black, basaltic lavas on the Moon, and for this reason we are somewhat in doubt in regard to the interior of those lunar craters which come under 1° and 2° of the color-scale; for example, some dark spots on *Mare Vaporum* and the dark interior of *Plato* and *Boscovich*. On the other hand, an undoubted agreement exists between lunar and terrestrial volcanoes for the lighter and brightest colors. Some of our craters show in their interior active solfataras; others do not. White coloration of more or less intensity can, however, be produced in various ways. This will be illustrated by the following example: The crater of the Lipari Island volcano had not been in marked activity since 1771; fumaroles, however, were plentiful, and, in 1813, the expulsion of boracic acid, sulphur, ammonia, and alum was commenced. On August 7, 1873, an increased activity of the fumaroles was noticed, and on September 7th an eruption — lasting three hours — followed, covering the island with white, siliceous ashes. The main peak of the volcano and its surroundings were covered with snow-white ashes, three to four *cm.* thick. Later on, ordinary light-gray ashes fell. In subsequent eruptions, especially in 1888, pieces of lava, bleached by acid fumes, and ordinary gray ashes were thrown out.

The light color of the interior of terrestrial craters is, however, most frequently produced by the products of fumaroles, and especially by the bleaching of lavas through acid fumes.

Solfataras upon fissures are of importance for the study of the Moon. On the exterior slopes of volcanoes in Chile, which are mostly covered by snow and ice, DOMEYKO distinguishes solfataras, which occur temporarily upon long fissures; and, locally limited, permanent ones. He observed a fissure, from eight to nine *km.* long, three months after its formation, in 1847, which traversed the trachytic highlands of the Cerro Azul, in the vicinity of the inactive volcano Descabezado Grande. Steam and fumes of sulphur issued from innumerable places, and, here and there, chlorine gas. Neither liquid lava nor ashes or pumice-stone were visible. A white, earthy mass covered the rocks exposed to the reactions of the fumaroles. On a second visit, in 1857, DOMEYKO found the emission of fumes greatly reduced;

and on a third visit, in 1873, action had ceased several years ago, and the color of the fissure had become darker.

Similar long, inactive solfataric fissures are known to exist in the same mountain range. The lateral solfataras, which are located several hundred metres below the rims of craters, show neither long fissures nor forcible eruptions, and they are permanent.

Now let us consider the bright spots on the Moon. They are in evident connection with single, large craters; they appear either inside the latter or on their external slopes, or else they radiate from them in long streaks. There is no case known where white spots occur on outer slopes or radiate from the crater, unless the latter is also white.

The brightest object on the Moon is *Aristarchus*, of 35.35 *km.* diameter. In its interior, says NEISON, is a second peak, with a small crater-opening, of 9½° brightness. The interior of *Aristarchus* is fully 9½°; the west wall, 6° to 8°; the south wall, 8°; the east wall, 9°; the north wall, 9½°; and the central peak is 10° in brightness, the latter being the brightest point on the Moon.

The most remarkable phenomena on the Moon are, however, the bright systems of radiations, of more or less width, which emanate from the exterior slopes of *Tycho*, *Copernicus*, *Kepler*, and other craters, and sometimes reach a length of several hundred *kilometres*.

Without showing perceptible relief, they cross high crater-mountains and depressions, losing brightness, and disappearing finally. In single cases, they terminate on a crater; sometimes they appear to fork, but they are rarely curved. What are these white radiations?

Professor SUESS says that they are the after-effects of volcanic activity,—*i. e.*, fumaroles upon small fissures,—and that the escaping fumes have partly deposited white sublimations, but principally have caused a discoloration and bleaching of the rocks.

This hypothesis may be opposed in two ways: Firstly, that the extent of this fissure and fumarole formation is far in excess of similar phenomena on the Earth. This, however, is only a difference in degree, and not in principle. Secondly, it may be said that such extensive effects of fumaroles presuppose the existence of steam.

SAINTE-CLAIRE-DEVILLE, BUNSEN, and FOUQUÉ have found that the emanation of fumes from large streams of lava follows certain rules. At a temperature above 500° C., the escaping fumes are anhydrous. Chlorine is characteristic of this phase, and sodium-chloride is sometimes deposited upon the rough surface of the lava. The second phase, at 300° to 400° C., are the acid fumaroles,—*i. e.*, hydrochloric and sulphurous acid, with a large quantity of steam. Then, at about 100° C., appear the alkaline fumaroles with sulphuretted hydrogen, also accompanied by steam in large quantities. Then follow, below 100° C., the cold fumaroles with steam, carbonic acid, and some sulphuretted hydrogen. Finally, carbonic acid is the principal product.

Professor SUESS expresses the opinion that, in view of the great length and width (up to 30 *km.*) of some of the bright lunar radiations, and assuming that they were formed by sublimations and by bleaching of rocks, steam is indispensable for their formation, and that an anhydrous chlorine emanation alone would not suffice.

It is well known that steam plays an important part in volcanic eruptions, and it has been formerly assumed that they were caused by water entering the hot and liquid interior of the Earth. While it cannot be denied that in special cases water comes in contact with liquid lava and increases the force of explosion, another explanation, known as ANGELOT'S theory, is now generally accepted. This theory is based upon the facts that all molten masses, be they metals, glass, or slags from blast furnaces, etc., absorb various gases, which escape violently upon cooling and solidification of the magma. Thus, for example, liquid silver absorbs oxygen; copper absorbs sulphurous acid; cast-steel absorbs oxide of carbon, hydrogen, and nitrogen; slags from blast furnaces absorb air and carbonic oxide, etc. According to experiments by BESSEMER, the escaping of gases from fluid cast-steel is greatly facilitated if the castings are allowed to cool in a vacuum, which is of importance in relation to the interpretation of phenomena on the Moon. If we compare the phenomena taking place in casting steel with those observed by DANA at the Hawaiian volcano *Kilauea* (a detailed description of which would take too much space), we find a remarkable agreement of all details; whereby the supposition that both phenomena are caused by the absorption and disengagement of gases is confirmed.

Now let us return to the Moon. We not only observe the absence of water, but also the absence of even a trace of sedimentary rocks, which cover such a large portion of our planet, with their folded mountain ranges, etc. What we see on the Moon are circular forms, large ones and small ones, with here and there an ellipse or a slight deviation from a circle. That is the naked surface of a solidified, formerly liquid, heavenly body. SUESS now describes the phenomena we may expect to take place in the cooling of a fluid globe. He draws attention to the fact that after a solid crust of a certain thickness has been formed, a re-fusion of the crust takes place here and there. The shape of such a fusion-hearth, as he calls it, is that of a globe-segment, and its circumference is a circle. Now the process approaches the end; the temperature of the surface becomes less at and near the rim of the hearth; the slags are pushed outward like moraines. Finally, a level surface remains, surrounded by a circular wall of slags, which may have an attitude of several thousand feet. Such, for example, are the enormous slag-walls, — which, under the names, the *Apennines*, the *Alps*, etc., — surround the *Mare Imbrium*. One of these slag-rings, viz.: the *Alps*, is intersected by a deep furrow, which has been designated as the Great Valley of the *Alps*. This furrow is about 130 *km.* long, has, in parts, very steep, straight-cut walls, about 3000 *m.* in height, and has a level bottom throughout. It begins, 9 *km.* wide, at *Mare Imbrium*, and runs, with regularly decreasing width, to *Mare Frigoris*. SUESS explains the formation (according to the last-taken P. W. photograph of the *Alps*), by assuming that the whole slag-field was broken from the east, and that the two fragments were horizontally pushed against each other. Such occurrences presuppose great mobility of the substrata, which is in harmony with what has been said about the fusion-hearths.

After the slag-crust on the surface of the Moon had increased in thickness, — this slag-crust will be designated in future as the lunar *lithosphere*, — the fusion-hearths were greatly diminished in diameter, and now gave rise, not to large *mare* formations, but to smaller rings, craters, and volcanic mountains. There is no doubt that the majority of the now existing craters are of more recent origin than most of the *mare* flats. Every one of these abysses is evidently an independent fusion-hearth. After renewed fusion of the lithosphere by internal heat, the escaping gases caused a pushing back of the solid slags, and, as a rule, an overflowing of lava. This process may have been repeated several times in the same crater.* As a rule, the bottom of the crater, as we see it now, is far below the average level of the surroundings. An exception, however, is formed by *Wargentin*, in which the lava has solidified near the rim of the crater, high above the surroundings. The depth of craters evidently depends upon the slower or quicker escape of gases, and sometimes upon lateral drainage of lava. EBERT has measured 92 of the lunar crater-mountains, and found that the slope of their exterior profiles is from 6° to 12°. Only *Plato* and *Tycho* are considerably steeper.

It is interesting to notice that, of terrestrial volcanoes, *Mauna Loa* has a slope between 3° 51′ and 6° 43′; and the Iceland volcanoes show still flatter angles. The interior slope of lunar craters, on the contrary, is very steep; as a rule, over 30°, often 40°, and for *Aristarchus* as much as 55°.†

The depth of lunar crater-bottoms below the immediate surroundings is rarely less than 500 *m.*; in most cases, 1000 to 2000 *m.*, and reaches in *Maurolycus* 3031 *m.*; in *Theophilus* 3411 *m.* In the latter crater, of 102.7 *km.* radius, the bottom is 4678 *m.* below the rim, and from the bottom rises a central peak, 2144 *m.* high. The bottoms of *Werner*, *Tycho*, and others are also over 4000 *m.* below their rims.

A peculiar phenomenon on the Moon is the frequent occurrence of groups of large craters. *Catharina*, *Cyrillus*, and *Theophilus*, for example, stand close together, and *Theophilus* extends far into *Cyrillus*. Why was the older crater inactive and a new one formed in close proximity? Terrestrial experience has taught us that isothermal lines run nearly parallel near the surface, but only reach full parallelism at greater depths. Now, if the lava in a crater of large dimensions has once completely solidified, the isothermal line is lower in this particular spot than in its vicinity, and renewed volcanic activity,—*i. e.*, a new supply of internal heat,— does not find the point of least resistance below the dead volcano, but in its immediate vicinity. The Hawaiian volcanoes, *Kilauea* and *Mauna Loa*, however, show that two adjoining volcanoes can be in activity simultaneously.

The lunar formations described had the following characteristics:

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* See HOLDEN, *Publications* A. S. P., Vol. III, page 250.

† See BECKER, geometrical form of volcanic cones, and the elastic limit of lava, *Amer. Jour. Sci.*, October, 1885.

First. — Their circumferences were circular, elliptic, or irregularly elliptic.

Second. — They had plainly visible walls, more or less flat on the outside, and steep inside.

Third. — They had well-defined, level, or slightly curved bottoms. Only to these the name of crater should be applied. They can be compared with terrestrial volcanoes of the Hawaiian type, and differ from the latter:

First. — In regard to their greater dimensions.

Second.—That their bottoms are considerably below the average level of immediate surroundings.

Third. — By the rarity of internal ruptures.

The surface of the Moon shows, however, many other forms which differ materially from those so far described; they are located partly inside and partly outside of craters.

Ptolomaeus (L. W. and P. W.), for example, shows upon a wide and nearly level lava-plain the so-called crater A., a circular opening, without visible bottom, upon a conical peak. Close to the north is a cup-shaped depression. In a terrestrial lava-field it would be said that such a depression was formed by the escape of a big bubble.

Sometimes two openings upon so-called central mountains are close together, as, for example, southeast of *Archimedes*, near the rim of *Mare Imbrium;* and sometimes they appear in the form of a figure 8. In *Clavius* such openings appear in great number, but separated. These bubble-like openings have so far all been designated as craters, which does not seem proper. So far as dimensions are concerned, their diameters may be as much as 15, and even 18, *km.*

SUESS expresses the opinion that their formation is due to a single explosion. They are a subject for further investigation.

In September, 1783, a long fissure was formed in the volcanic regions of Iceland, not radiating from a main crater, but belonging to a system of fissures, which, following a curved depression, traverses the whole of Iceland. It has been called the *Laki* fissure, because it intersects the mountain *Laki.* THORODDSEN followed this fissure for about 30 *km.*, and found it disappearing to the northeast in the ice-fields of the *Skaptar Jökull.* All along the *Laki* fissure are crater-cones, of which the highest is only 150 *m.* THORODDSEN counted about 100 of them. They have been formed by the throwing up of slag and ashes; from them, as well as from the fissure itself, enormous masses of lava have escaped.

The surface of the moon shows formations that remind us of the *Laki* fissure. They have evidently been formed not by fusion, but after the lunar lithosphere had become more solid. JUL. SCHMIDT has called them crater-rills. In recent (L. W.) photographs, the most remarkable of these formations runs near the south base of *Ptolemaeus*, and at least eight places of eruption have been counted on it.

While their connection with fissures is undoubted, it is not yet known whether cones exist upon lunar crater-rills or only funnels. Here is room for further observation.

Another peculiar phenomenon is presented by the high ridges traversing the *Ariadaeus* fissure: some of the ridges are intersected by the latter, and others are not. (P. W.) Here it might become possible to decide whether lava-streams of great length have flowed upon the Moon.

In concluding his interesting paper, Professor SUESS makes the following suggestions:

First. — Some observers say that bright streaks on the Moon appear differently on the photographs, and as seen by direct vision. A comparison with photographic effects of light-colored terrestrial volcanic products would be desirable.

Second.—The construction of the lunar Alpine Valley, especially its western half, is of such importance for the study of large slag-fields that its details should be observed with great care.

Third.— Of equal importance in other respects is the study of *Wargentin*. This crater, with its sea of lava solidified while the latter was overflowing, is unique on the Moon.

Fourth.— Between the fusion-craters with flat bottoms and the explosion openings we find two doubtful types. The one — for example, *Alpetragius*, — seems to have a certain similarity with Vesuvian structures. An accurate determination of the slopes of *Alpetragius*, the condition of its central opening, etc., is desirable. The second type comprises openings like *Ptolemaeus A.*, which have been compared with bubbles, and are of unknown origin.

Fifth.—The majority of openings upon fissures do not seem to possess walls. It would be of importance to know whether anywhere a cone exists upon a fissure. Besides, it should be determined for large fissures whether ridges intersect them uninterruptedly in such a manner that the existence of comparatively recent lava-streams could be assumed.

No one can deny the importance of the study of lunar phenomena in relation to terrestrial geology. We see here, as it were, our own globe in its infancy. In both celestial bodies the following phases can be classified:

I. Fusion of the lithosphere in large plains. (*Mare Serenitatis;* not observable on the Earth.)

II *a*. Fusion without reaching the surface. (*Batholithes*, granite of the *Erzgebirge;* not known on the Moon.)

II *b*. Fusion-hearths of small diameter; quiet boiling of lava. (Hawaiian volcanoes: *Ptolemaeus*, *Wargentin*.)

III. Formation of fissures, narrow chimneys, and rhapsodic explosions. (*Laki*-fissure, *Vesuvius;* crater-rills, *Hyginus*.)

Finally, as local consequences of single eruptions, we mention the different phases of fumaroles which have been assumed to exist on the Moon also.

PLANET NOTES FOR JULY AND AUGUST.

By Professor Malcolm McNeill.

July.

Mercury passes inferior conjunction with the Sun on the morning of July 1st, and becomes a morning star. It moves rapidly away from the Sun, and reaches west elongation on the evening of July 22d. For the rest of the month it rises a little less than an hour and a half before the Sun, and is in good position for observation.

Venus is in good position for evening observation. It reaches greatest east elongation, 45° 31′, on the morning of July 11th. It then remains above the horizon $2^h\ 20^m$ after sunset. This is not as long as it was during June, although the distance from the Sun is greater. This shortening of the time between sunset and the setting of the planet is due to the fact that the planet is far to the south of the Sun; and the difference of declination increases throughout the month, so that on July 31st the planet sets less than two hours after sunset.

Mars is becoming harder to see as it gradually draws nearer to the Sun. By the end of the month it sets only about an hour after sunset; and it it will, after that, be practically impossible to see it with the naked eye until winter, after it has passed conjunction with the Sun, and come out on the other side far enough to be seen as a morning star before sunrise. It can probably be seen during the first part of the month, but it has nearly reached its minimum brightness, and it will not be an easy object. There will be a very close conjunction with the Moon on July 22d, and the planet will be occulted in some parts of the country shortly before the two-day-old Moon sets.

Jupiter is too near the Sun for good observation. It is in conjunction with the Sun on July 10th, and changes from an evening to a morning star. By the end of the month it rises rather more than an hour before sunrise, and may be seen under good weather conditions.

Saturn is in good position for evening observation. It is on the meridian a little before sunset on July 1st, and may be seen in the southwestern sky until nearly 1 A.M. At the end of the month it sets two hours earlier. It retrogrades until July 4th, and then begins to move slowly eastward among the stars, but the whole motion is only about equal to the Moon's diameter. It is about 10° east of the first magnitude star *Spica, Alpha Virginis.*

Uranus is in the constellation *Libra*, and follows after *Saturn* about an hour, and is about 7° south. It retrogrades slowly until July 24th, and then begins to move eastward, the westward motion being about a semi-diameter of the Moon. The easiest star by which to identify the planet is the third magnitude *Alpha Libræ.* The planet, about sixth magnitude, is 2° east and 1° south of the star.

Neptune is to be seen in the morning shortly before sunrise, but only by the aid of a telescope, it being too faint for naked-eye observation. It is in the constellation *Taurus.*

AUGUST.

ECLIPSE.—There will be a partial eclipse of the Sun on August 20th, visible only in northeastern Europe and northwestern Asia. The maximum obscuration of the Sun will be a little more than one-fourth of its diameter.

Mercury is a morning star at the beginning of the month, rising about 1^h 20^m before the Sun. The distance between planet and Sun rapidly lessens, and superior conjunction occurs on August 17th. The planet may be seen for a few days at the beginning of the month. There is a very close conjunction with *Jupiter* on August 1st. The least distance between the planets is only 9′, but this occurs after sunrise in this country.

Venus is still an evening star, but is rapidly drawing nearer to the sun, and on August 31st sets only half an hour later. It is, however, at its maximum brightness during the month, as it is now about half-way between elongation and inferior conjunction; and will be bright enough to be seen by daylight, if one knows where to look for it. It is about 16° south of the Sun, and its distance east of the Sun varies from 41° on August 1st to 21° on August 31st.

Mars is still an evening star, but is too close to the Sun to be seen by the naked eye. At the end of the month it sets a little more than half an hour after sunset.

Jupiter is a morning star, and is getting far enough away from the Sun to be conspicuous in the early morning. At the beginning of the month it is 7° south of *Pollux (Beta Geminorum)*, and during the month it moves about 6° eastward.

Saturn is still in good position for observation, but sets two hours earlier than during the corresponding part of July. It moves eastward about 2° in the constellation *Virgo*, and on August 31st it is about 40′ south of the fourth magnitude star *Kappa Virginis*. The rings which narrowed up very slightly during May and June are now widening again, and at the end of the month the ratio of minor to major axis is about $\frac{3}{10}$. The minor axis of the rings is about two-thirds of the polar diameter of the planet.

Uranus still keeps its position relative to *Saturn*, following after it about an hour. It is in the constellation *Libra*, and moves slowly eastward during the month a distance about equal to the Moon's diameter. It may still be identified by its position relative to *Alpha Libræ*, a little more than 2° east and 1° south.

Neptune is to be found in the constellation *Taurus*, in the early morning hours before sunrise.

EXPLANATION OF THE TABLES.

The phases of the Moon are given in Pacific Standard time. In the tables for Sun and planets, the second and third columns give the Right Ascension and Declination for Greenwich noon. The fifth column gives the local mean time for transit over the Greenwich meridian. To find the local mean time of transit for any other meridian, the time given in the table must be corrected by adding or subtracting the change per day, multiplied by the fraction whose numerator is the longitude from Greenwich in hours, and whose denominator is 24. This correction is seldom much more than 1^m. To find the standard time for the phenomenon, correct the local mean time by *adding* the difference between standard and local time if the place is west of the standard meridian, and *subtracting* if east. The same rules apply to the fourth and sixth columns, which give the local mean times of rising and setting for the meridian of Greenwich. They are roughly computed for Lat. 40°, with the noon Declination and time of meridian transit, and are intended as only a rough guide. They may be in error by a minute or two for the given latitude, and for latitudes differing much from 40° they may be several minutes out.

PHASES OF THE MOON, P. S. T.

		H. M.
Full Moon,	July 6,	3 29 P. M.
Last Quarter,	July 14,	7 31 P. M.
New Moon,	July 21,	9 32 P. M.
First Quarter,	July 28,	12 36 P. M.

THE SUN.

1895.	R. A. H. M.	Declination. ° ′	Rises. H. M.	Transits. H. M.	Sets. H. M.
July 1.	6 41	+ 23 8	4 36 A. M.	12 4 P.M.	7 32 P.M.
11.	7 22	+ 22 7	4 42	12 5	7 28
21.	8 2	+ 20 29	4 50	12 6	7 22
31.	8 42	+ 18 17	4 58	12 6	7 14

MERCURY.

1895.	R. A. H. M.	Declination. ° ′	Rises. H. M.	Transits. H. M.	Sets. H. M.
July 1.	6 40	+ 18 38	4 53 A.M.	12 3 P.M.	7 13 P.M.
11.	6 22	+ 18 50	3 56	11 6 A.M.	6 16
21.	6 37	+ 20 34	3 24	10 41	5 58
31.	7 30	+ 21 37	3 34	10 55	6 16

Venus.

1895.	R. A. H. M.	Declination. ° ′	Rises. H. M.	Transits. H. M.	Sets. H. M.
July 1.	9 49	+ 14 40	8 18 A.M.	3 12 P.M.	10 6 P.M.
11.	10 26	+ 10 29	8 30	3 9	9 48
21.	10 59	+ 6 7	8 38	3 3	9 28
31.	11 27	+ 1 46	8 42	2 51	9 0

Mars.

July 1.	9 3	+ 18 10	7 17 A.M.	2 25 P.M.	9 33 P.M.
11.	9 27	+ 16 16	7 12	2 11	9 10
21.	9 52	+ 14 11	7 3	1 55	8 47
31.	10 16	+ 11 57	6 56	1 40	8 24

Jupiter.

July 1.	7 9	+ 22 39	5 6 A.M.	12 32 P.M.	7 58 P.M.
11.	7 19	+ 22 23	4 38	12 2	7 26
21.	7 29	+ 22 5	4 10	11 32 A.M.	6 52
31.	7 37	+ 21 45	3 43	11 3	6 23

Saturn.

July 1.	13 57	− 9 18	1 48 P.M.	7 19 P.M.	12 50 A.M.
11.	13 57	− 9 21	1 9	6 40	12 11
21.	13 58	− 9 28	12 31	6 1	11 31 P.M.
31.	13 59	− 9 38	11 53 A.M.	5 23	10 53

Uranus.

July 1.	14 55	− 16 20	3 10 P.M.	8 16 P.M.	1 22 A.M.
11.	14 54	− 16 18	2 30	7 36	12 42
21.	14 54	− 16 17	1 51	6 57	12 3
31.	14 54	− 16 17	1 11	6 17	11 23 P.M.

Neptune.

July 1.	5 2	+ 21 21	3 4 A.M.	10 24 A.M.	5 44 P.M.
11.	5 3	+ 21 23	2 26	9 46	5 6
21.	5 4	+ 21 25	1 49	9 9	4 29
31.	5 6	+ 21 26	1 10	8 30	3 50

PHASES OF THE MOON, P. S. T.

		H. M.
Full Moon,	Aug. 5,	5 51 A. M.
Last Quarter,	Aug. 13,	9 18 A. M.
New Moon,	Aug. 20,	4 56 A. M.
First Quarter,	Aug. 26,	9 43 P. M.

THE SUN.

	R. A.	Declination.	Rises.	Transits.	Sets.
1895.	H. M.	° ′	H. M.	H. M.	H. M.
Aug. 1.	8 46	+ 18 2	4 59 A.M.	12 6 P.M.	7 13 P.M.
11.	9 24	+ 15 17	5 9	12 5	7 1
21.	10 1	+ 12 8	5 18	12 3	6 48
31.	10 38	+ 8 39	5 28	12 0	6 32

MERCURY.

Aug. 1.	7 38	+ 21 34	3 37 A.M.	10 58 A.M.	6 19 P.M.
11.	8 59	+ 18 44	4 30	11 40	6 50
21.	10 18	+ 12 24	5 34	12 20 P.M.	7 6
31.	11 25	+ 4 47	6 29	12 48	7 7

VENUS.

Aug. 1.	11 29	+ 1 21	8 41 A.M.	2 49 P.M.	8 57 P.M.
11.	11 50	− 2 38	8 36	2 31	8 26
21.	12 2	− 5 56	8 21	2 4	7 47
31.	12 3	− 7 59	7 48	1 25	7 2

MARS.

Aug. 1.	10 18	+ 11 43	6 56 A.M.	1 39 P.M.	8 22 P.M.
11.	10 42	+ 9 21	6 49	1 23	7 57
21.	11 5	+ 6 53	6 41	1 7	7 33
31.	11 29	+ 4 19	6 33	12 51	7 9

JUPITER.

Aug. 1.	7 39	+ 21 43	3 40 A.M.	11 0 A.M.	6 20 P.M.
11.	7 48	+ 21 21	3 10	10 29	5 48
21.	7 57	+ 20 59	2 40	9 59	5 18
31.	8 5	+ 20 35	2 10	9 28	4 46

SATURN.

Aug. 1.	14 0	− 9 39	11 49 A.M.	5 19 P.M.	10 49 P.M.
11.	14 2	− 9 52	11 12	4 42	10 12
21.	14 4	− 10 8	10 36	4 5	9 34
31.	14 7	− 10 26	10 1	3 29	8 57

URANUS.

Aug. 1.	14 54	− 16 18	1 8 P.M.	6 13 P.M.	11 18 P.M.
11.	14 54	− 16 20	12 30	5 35	10 40
21.	14 55	− 16 23	11 51 A.M.	4 56	10 1
31.	14 56	− 16 28	11 13	4 18	9 23

NEPTUNE.

Aug. 1.	5 6	+ 21 26	1 7 A.M.	8 27 A.M.	3 48 P.M.
11.	5 7	+ 21 27	12 27	7 48	3 9
21.	5 8	+ 21 28	11 49 P.M.	7 10	2 31
31.	5 8	+ 21 28	11 10	6 31	1 52

SPECTROSCOPIC OBSERVATIONS OF *SATURN* AT THE ALLEGHENY OBSERVATORY.

By Dr. James E. Keeler.*

As certain observations of mine on the spectrum of *Saturn* have been widely noticed by the daily press, and various reports have been spread, some of which are correct and some incorrect, but none of which were made by my authority, I take this opportunity to explain the real character of the observations. It is hardly necessary for me to say here that I have made no "claims" whatever respecting them.

The observations furnish a direct proof of the accepted hypothesis that the ring of *Saturn* consists of a multitude of small bodies revolving around *Saturn* in circular orbits. The hypothesis is an old one, but its universal acceptance dates from the publication of Maxwell's prize essay in 1859. While the mathematical proofs given by Maxwell and his predecessors are conclusive, a demonstration of the hypothesis by the widely different method of direct observation with the spectroscope is not, I think, without interest.

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* Director of the Allegheny Observatory.

The proof depends upon an application of the well-known principle of DOPPLER, by which the motion of a heavenly body in the line of sight can be determined by measuring the displacement of a line in its spectrum. Under the two different hypotheses, that the ring is a rigid body, and that it is a swarm of satellites, the relative motion of its parts would be essentially different; hence, to distinguish between these two hypotheses it is only necessary to find a method of sufficient delicacy, in order to bring the question within the province of the spectroscope. Any method depending on the successive comparison of the spectra given by different parts of the ring would be almost certain to fail. The method which I have employed is explained below.

If two planes, at right angles to each other, are passed through the observer and the system of *Saturn*, one (A) passing anywhere through the system and the other (B) through its center, the velocity, resolved in the direction of the line of sight, of any point on the surface of the system where it is intersected by plane A can be expressed as a function of the perpendicular distance of the point from plane B. It is only necessary to consider the case when the plane A is parallel to the major axis of the apparent ring. On the assumption that the ball of *Saturn* rotates as a solid body, and the ring as an assemblage of particles, each of which moves with a velocity determined by KEPLER'S third law, the expressions for the ball and for the ring are very different, the former being linear, and the latter an equation of a degree higher than the second. I have determined these expressions for the special case above mentioned. They are still further simplified by assuming that plane A also passes through the center of the planet.

Now, if we bring the image of *Saturn*, formed by a telescope, upon the slit of a spectroscope, with the slit in the intersecting plane A, the expressions above referred to are also the equations to the curves of which the lines in the spectrum of the planet are a part, referred to an undisplaced spectral line and the perpendicular line through its center as axes; for, in these curves, x is proportional to the perpendicular distance from plane B, and, by DOPPLER'S principle, y is proportional to the velocity in the line of sight. The simplest case is, of course, that in which the slit coincides with the major axis of the ring; this is also the condition for which the differential velocity of points on the surface of the ring is a maximum, and it is one which can be approximately realized in observation.

Hence the laws of rotation of the component parts of the system can be determined (within certain limits) by the *form* of the special lines, and the form can be determined with very considerable accuracy by photographing the spectrum with a suitable instrument.

According to the assumptions which have been made above, and which represent the accepted hypothesis, lines in the spectrum of the ball are straight, but inclined; as compared with their direction the general inclination of the (theoretically) curved lines in the spectra of the opposite sides of the ring is smaller, and it is *reversed.* The actual aspect of the lines on my photographs is in exact accordance with that required by the hypothesis.

If the ring rotated as a whole, the lines in its spectrum would be straight, and their direction would pass through the origin; they would be very nearly prolongations of the planetary lines. Such an aspect of the lines as this could be recognized on my photographs at a glance.

The direction of a line free from displacement was obtained by photographing the spectrum of the full Moon on the same plate, on each side of the spectrum of *Saturn.*

For further details, with the numerical results of measurement of the plates, I must refer to the May number of the *Astrophysical Journal*, in which I have described these observations at some length.—From *Science*, May 10, 1895.

ON A METHOD OF PHOTOGRAPHING THE CORONA DURING A TOTAL ECLIPSE, BY WHICH EACH PART MAY BE GIVEN ANY EXPOSURE DESIRED ON THE SAME PHOTOGRAPHIC PLATE.

By CHARLES BURCKHALTER.

Within the last few years the corona has been so systematically photographed, and with instruments so dissimilar in aperture and focal length, that it may be considered as firmly established that no two parts of the corona, differing considerably in distance from the Moon's center, should receive equal exposure times—the extreme outer part requiring from twenty to one hundred times more exposure than that at the Moon's limb—and, on account of this wide range of exposure, no one negative has ever shown more than a comparatively small portion *properly* exposed. As a proof of this assertion, I need only call attention to two of the superb negatives made by Professor SCHAEBERLE, of the LICK Observatory Eclipse Expedition to Chili, in April, 1893, where, for the two in question, the exposures given were one-fourth second and thirty-two seconds, and, while the short exposure gave a negative showing a bewildering amount of detail within 10′ of the Moon's limb, not a vestige of the middle or outer corona appears; yet, in the long exposure, which shows it to a distance of about 3° from the Moon's center, there is no trace of the delicate detail so exquisitely shown in the quarter-second negative, it having been, as Professor SCHAEBERLE graphically expresses it, "burned out" by over-exposure.* I take it for granted that all the above is so well understood by astronomers that argument is unnecessary. These negatives are on a grand scale (the Moon's image is 4.4 inches), and stand quite alone in their perfection, and, possibly, the present method reached its zenith with SCHAEBERLE'S triumph, although it must be admitted that, in the first example, the outer corona received only the 128th part of the proper exposure, and, therefore, is not shown at all, while in the latter, the inner corona, the most valued part, received 128 times too much.

A new method of photographing the corona is, then, it seems, a necessity, if we are to have anything more than properly exposed fragments and the resultant "ideal" drawing; and this method, if it is to *completely* solve the problem, must be capable of giving the corona at the Moon's limb only one second or less exposure during the time the extreme outer parts, to the very limit of distance possible to photograph, are fully exposed, and, that too, at the same time, and upon the same plate.

I have recently completed a mechanical device by which any exposure desired can be made with great exactness, well within and beyond the requirements asked for above, providing the proper exposure time for the various distances from the Moon's limb can be approximately predicted, and, as astronomers now have such a great variety of negatives for comparison, this is at least possible.*

I expect to give this method a practical test in Japan at the eclipse of August 8, 1896. I shall be able to make at least four, and probably six exposures during the total phase (about $2^m 30^s$), and, as I can carry out any exposures desired (barring accident and unskillful work), I hope to obtain some good negatives. The correct exposure for this particular eclipse then is of the very greatest importance, and I hope to receive valuable suggestions from astronomers, giving me, for intervals of about 4′ outward from the Moon's limb to a distance of 108′ from the Moon's center, their ideas and judgment of a perfect exposure. Each exposure will be independent of all the others, and may be widely different; therefore, four to six ideal exposures can be tried.

The lens and tube of the photographic telescope I shall use are now being made by BRASHEAR, at the expense of a prominent member of the A. S. P., who will also provide a first-class equatorial mounting, with driving clock, etc. The lens will have an aperture of four inches, and focal length of fifteen feet, giving an image of the Moon about 1.7 inches. The plates will be twelve by twelve inches, and will permit controlling the exposure to about 108′ from the Moon's center.

At the present writing, while I have come to no definite conclusion, the following exposures have received some consideration, the exposures contemplated at the Moon's limb, and five other points only being given, and in the probable order of exposure:

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* The apparatus was shown and explained by the writer at the meeting of the **A. S. P.**, held at the LICK Observatory, June 8, 1895.

At Moon's limb.		At 26′	At 46′	At 66′	At 86′	At 108′
	s.	s.	s.	s.	s.	s.
A,	.4	.9	1.4	2.4	3.6	5.0
B,	.8	1.2	2.5	4.5	8.4	15.0
C,	.6	1.	3.3	7.2	15.9	30.0
D,	1.	4.	9.0	14.	20.	24.0
E,	1.5	1.8	2.6	3.9	6.2	10.0
F,	.3	.6	1.6	3.1	5.3	10.0

The apparatus for one negative is ready for the field (after an exposure has been decided upŏn) at the present time.

The apparatus would be difficult to describe, properly, without drawings, but the principle may be easily understood. Narrowed down to a few words, it consists of a diaphragm, properly shaped to give the required exposure, rapidly rotating close to, and immediately in front of the photographic plate, the movement being given by a driving-clock attached to the back and outside of the plate-holder, the arbor that carries the diaphragm passing from the driving-clock through a small hole in the middle of the plate, at the point that would ordinarily be occupied by the center of the Moon's image.

The shape of the diaphragm, which may be readily computed for any exposure, may be any one of several forms, but all take one of the various shapes of the cam.

The shape I have adopted is that of a double cam, one being inverted, and it is perfectly balanced without counter-weight, so that steady motion is assured. The driving-clock will run about fifteen minutes, and when newly wound, the diaphragm turns about five times a second, and so far as I can find, is entirely free from jar. The driving-clock starts automatically, a device having been added that promptly sets it in motion when the plate-holder is lifted by the hand to be placed in position in the telescope, thereby again narrowing the opportunity of making a failure. The holes in the plates I have for experiment are five-sixteenth of an inch, and the arbor that carries the diaphragm one-sixteenth. I do not consider the small hole in the plate as a serious objection, the Moon's image on the negative being clear glass, nor is the hole really necessary, for there are other ways of giving the required exposure without in any way changing the plate, and I will briefly mention a few of the methods that I have considered, but I have pinned my faith to the one above described as being simple in the extreme, and as it has that *very* important feature, *perfect reliability.*

Where large images of the Moon are obtained, it can be done by suspending immediately in front of the plate, in the same manner as the "flat" in a Newtonian reflector is supported, a small and compact driving-clock to carry and turn the diaphragm; or, the clock and diaphragm could be held in position by a thin bar placed edgewise to the plate; or, the diaphragm alone could be supported by the bar and revolved by bevel gears driven by a clock outside the plate-holder. Either of these methods, however, would leave a very small portion of the plate unexposed (the part covered by the bar), which is an objection.

A small driving-clock with the diaphragm, could be attached to the plate itself, when the Moon's image is very large, so that no part of the corona would be cut off; but I can think of many objections to this method.

I spent some time upon a practical, but rather complicated device, consisting of a moving arm, working from a center behind the plate-holder, and in a line with its center, extending over to, and immediately in front of the plate, the motion to the diaphragm being given automatically by the motion of the arm across the plate by means of a cord wound upon a drum. The arm would be of flat steel, set edgewise to the plate and moving over an arc of 200 to 300 degrees. The parts of the plate swept over by the arm would get about a hundredth part less exposure than the other parts, but this small difference could be ignored.

My ideal device could only be used (without undue complications) with a photoheliograph, where the plate would be stationary and perpendicular, and the operator within the camera. It would consist principally of a ring in front of the plate, held in position by three or more guide-wheels, and rapidly rotated by a pinion; or, better, a belt from a wheel in the same plane. The center of the ring would be occupied by the center of the diaphragm, which would be attached to a cross-bar, held by two studs in the periphery, movable in two directions for precise adjustment.

A friend, to whom I explained my method, said: "The problem of exposing a *circular* corona, you have completely

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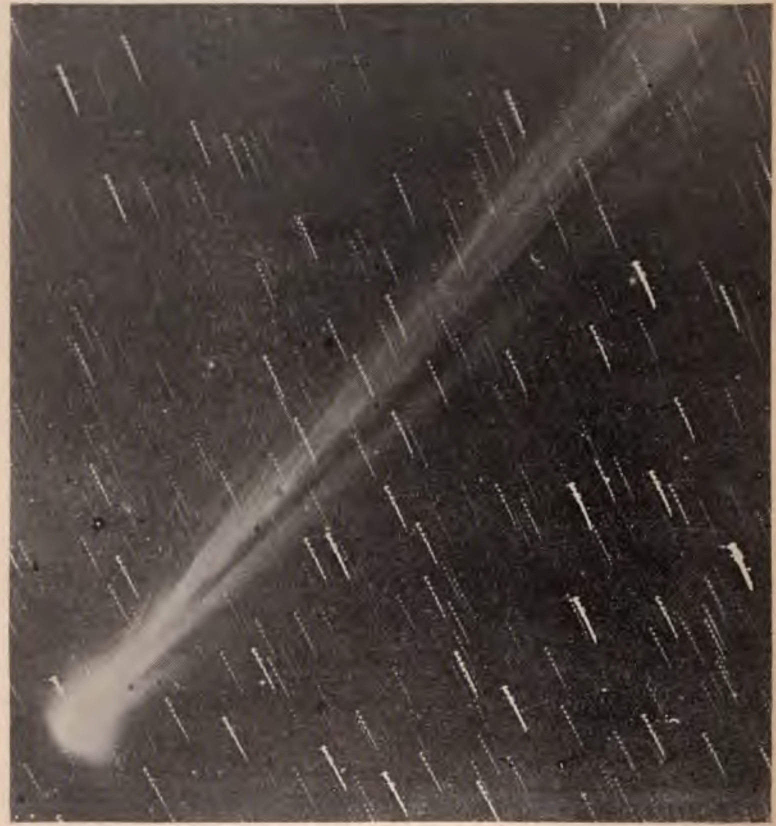


COMET RORDAME, JULY 12, 1893.

9h 00m — 10h 12m P. S. T.

Photographed by W. J. HUSSEY, at the LICK Observatory.

solved, but can you not give the faint polar regions more exposure than the bright equatorial streamers?" This can be done by placing somewhere between the source of power for driving the diaphragm and the diaphragm itself, two or more elliptical gear-wheels, which can be made to give a variable motion, giving the polar region from a small fraction to many times more exposure than that received by the equatorial parts. Another friend believes this ought not to be done, as we *want* this difference to show upon the plate.

I constructed a model, giving the polar regions twice the exposure received by the equator (in the same zones) and it is entirely reliable, but I do not expect to employ this feature at the coming eclipse. Finally, it should be said that my experiments have been conducted at the expense of a fund placed at the disposition of the LICK Observatory by Mrs. PHEBE HEARST, a member of this society.

CHABOT OBSERVATORY, Oakland, Cal., June, 1895.

A STUDY OF THE PHYSICAL CHARACTERISTICS OF COMET RORDAME.

BY W. J. HUSSEY.

On the evening of July 8, 1893, Mr. ALFRED RORDAME, an amateur astronomer residing in Salt Lake City, discovered a bright comet in the constellation *Lynx*. He at once reported his discovery to the WARNER Observatory, and within a day or two the news had been communicated to astronomers throughout the world. The comet was discovered independently about the same time in many places. It had also been seen previously as a "hazy star," and even in the preceding month it had been observed by an amateur astronomer, who mistook it for another comet, already known.

For nearly two weeks it was a conspicuous object in the western sky during the early portion of the night. It was then at its greatest brilliancy, and, in most respects, in a very favorable situation for observation. It was near the Earth and near the Sun. On the day of its discovery it passed the point in its orbit nearest the Earth, at a distance of about 38,000,000 miles. On the preceding day it had passed perihelion at a distance of 62,700,000 miles from the Sun. Its motion was retrograde, the plane of its orbit being inclined 159° 58′ to the plane of the ecliptic. The circumstances of its motion were such that shortly after perihelion passage it and the Earth were moving nearly in opposite directions. In consequence of this, its distance increased rapidly. In ten days (July 18th) it had become 58,000,000, and in a month (August 8th), 130,000,000 miles. Its light also decreased rapidly. On the 8th of August its theoretical brightness was only one twenty-fifth as great as at the time of its discovery, and very few observations were made after this time.

For a few days after the discovery the tail was bright, and, under the most favorable atmospheric conditions, could be traced more than twelve degrees with the naked eye. Moreover, it passed rapidly toward the position in which it could be observed in its true proportions. On July 11th (18^h G. M. T.) the angle between the line of sight and a line drawn through the Sun and comet was, approximately, 50°. The tail was then foreshortened by projection about twenty-three per cent. A week later the angle had increased to 82°, and the tail was then foreshortened only one per cent. On July 20th the tail was perpendicular to the line of sight, and it was then seen in its true length.

The Moon was absent when the comet was discovered. New Moon occurred on July 13th, but it was not until five days later that its light produced sufficient illumination of the sky to affect the photographic work which was being done. The absence of the Moon at this critical time, during which the comet was in the most favorable position for observation and at its greatest brilliancy, was a most fortunate circumstance.

During June and July, 1893, I was photographing various celestial objects — nebulæ, the *Milky Way*, etc., with the CROCKER telescope of the LICK Observatory. The appearance of the comet enabled me to obtain a valuable series of photographs of it, which I have recently examined with greater care than I was able to do at the time they were taken.

The CROCKER telescope is provided with a large portrait lens (WILLARD lens), having an aperture nearly six inches in diameter, and with an equivalent focal length of 30.82 inches. The negatives obtained with this telescope have, therefore, a scale of 1° = 0.538 inches, or, 1 inch = $1^\circ.86$. The use of such lenses in astronomical photography is too well known to require any comment. Their short focal length and great light power render them especially suitable for photographing faint, extended objects, such as comets, large nebulæ, and the *Milky Way.*

Thirteen photographs of the comet were secured — eleven with the CROCKER telescope, and two with a small camera having a lens about an inch and a quarter in diameter, and an equivalent focal length of about eleven inches. Six of the photographs are very good. They were obtained with exposures ranging from an hour to an hour and twenty minutes in length. They were taken to obtain as complete pictures of the comet as possible, in the time that it remained sufficiently above the horizon after dark to be successfully photographed. Three short exposures of six and eight minutes were made to form an idea of the photographic intensity of the comet's light, and to obtain evidences of rapid changes of form in the structure of the comet itself. Considering the shortness of these exposures, the results are very good. One of them has been particularly valuable in enabling the velocity to be determined with which the matter composing the tail was receding from the head. The two other photographs, obtained with the CROCKER telescope, are the results of the first night's work, July 11th. They were the least successful of all the photographs. The first plate used was defective and comparatively slow, and the exposure was cut short at the end of twenty minutes by the view in the finder being obstructed by the lower part of the slit of the dome. The finder was on the lower side of the telescope, for that position, and at some distance from it. Had the difficulty been foreseen, and the finder placed on the opposite side of the telescope, as was done the next night, the exposure might have been continued three-quarters of an hour longer, and another good photograph obtained. The plates were changed, and an exposure of forty-five minutes made, with no attempt to correct the motion of the telescope for the proper motion of the comet. The result was a comet-trail possessing considerable interest.

On two occasions a small camera (6½ × 8½) properly focused was removed from its tripod and secured to the telescope by means of a strong cord. Exposures with it and the telescope were then made at the same time. One of these photographs is particularly interesting in showing what can be done with a small lens, an inch and a quarter in diameter. An exposure of seventy minutes gave a negative having sufficient density to enable prints to be made from it, showing fully twelve degrees of the tail of the comet, with its principal peculiarities, and the trails of more than 500 stars. The stars photograph very quickly, even with very small apertures. In the course of some experiments on reduced apertures, I found that with the aperture of the CROCKER telescope reduced to a central circular area of one-fourth of a square inch, *Polaris* was distinctly photographed with an exposure of less than four seconds. An exposure of two seconds was not sufficient to give a developable image.

A few of the plates used in photographing the comet were SEED 26 x. Most of them, however, were coated with an unusually sensitive emulsion by CRAMER, Emulsion 6715. In photographing other objects,— the *Andromeda Nebula*, for example,— the results obtained with these plates showed them to be more than twice as rapid as the SEED 26 x plates. The success of my photographs of the comet, and especially of the short exposures, is largely due to this.

The sensitiveness of these plates stands in marked contrast to those which were used in the early attempts to photograph comets. In 1874 COGGIA'S comet was very bright, but the attempts to photograph it were not attended with success. In consequence of this, the comet's light was said to possess but little photographic intensity; in reality the plates were slow.

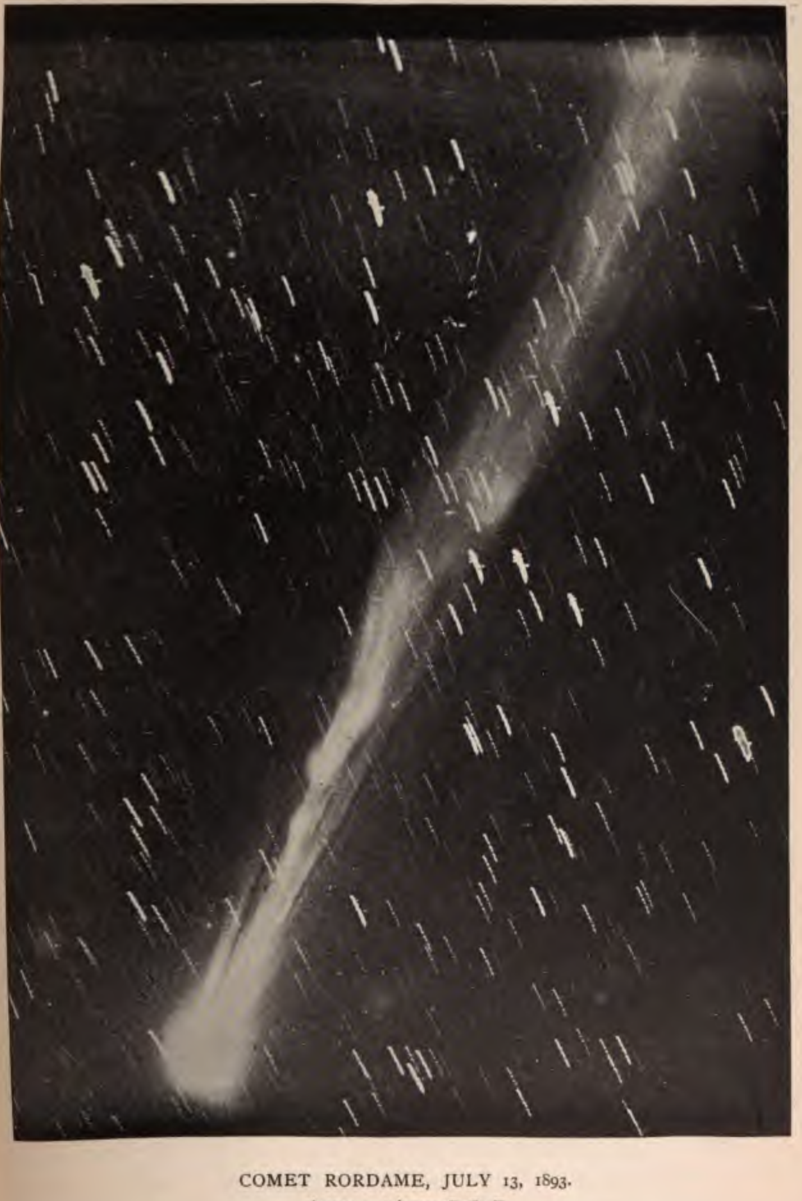
The principal comet of 1881 (Comet 1881, III), discovered by Mr. TEBBUTT, of New South Wales, was also very bright, and is distinguished in being the first comet to have not only its form but also its spectrum photographed. Dr. DRAPER, of New York, with an exposure of two hours and forty-two minutes, obtained a negative showing the head of the comet, about ten degrees of its tail, and the trails of many stars. A few days later he photographed its spectrum. In this he had been anticipated by Dr. HUGGINS, in England, who obtained a photograph of the comet's spectrum on June 24, 1881, the same evening that Dr. DRAPER had secured his first, not best, photograph of the comet itself. At Paris, M. JANSSEN was also at work about the same time, and he succeeded in obtaining a photograph showing the head and about two degrees of the tail.

Still more successful were the photographs of the Great Comet which appeared in 1882. At the Royal Observatory at the Cape of Good Hope, a camera provided with a large portrait lens was strapped to a telescope and a number of good photographs obtained of this, the most magnificent comet which has appeared during the last third of a century, its last splendid predecessor being the great comet of DONATI, in 1858. Magnificent as it was, it did not receive from photographers the attention it deserved, which, of course, is not very surprising, for astronomical photography was then in its infancy. The next ten years, however, were ones of great progress in this line of astronomical work. The modern dry plate was improved and brought to a high degree of perfection; telescopes designed especially for photography were constructed, and others remodeled, so as to enable them to do this kind of work. At present the photographic equipment in the hands of astronomers is very extensive, and if another comet were to appear like the great one of 1882, or, very much better, like that of DONATI in 1858,—for the latter was in a better situation for observation,—it would be photographed hundreds and perhaps thousands of times, and the photographs obtained would afford a larger amount of accurate data for the study of *certain* kinds of cometary phenomena than has been obtained visually from all the comets of the past.

Visual observations have shown that many comets have undergone very considerable changes of form in short periods of time. Such changes have, naturally enough, been more frequently noted and have excited greater attention and comment in the case of great comets than in small ones. As long as the information concerning these changes depended solely on the more or less uncertain visual impressions of the observers, and on the necessarily imperfect sketches made by them, there were often good reasons for doubting the correctness of the observations, so far, at least, as concerned the less conspicuous changes. But the changes which have been observed visually do not compare with those which have been revealed by photography, and of the reality of the latter there can be no question. Even the comparatively small comets of recent years, notably that discovered by SWIFT in 1892, those by RORDAME and BROOKS in 1893, and that by GALE in 1894, have furnished photographs showing the most marked differences from day to day, and differences, too, which were not detected visually.

It is to be noted, however, that many of the changes which have been best observed visually have related to nuclei, envelopes, luminous sectors, and other phenomena connected with the heads of the great comets; whereas, those best observed photographically have related more particularly to the streamers and condensations composing the tails. No great comet has appeared since photography has reached its present development, and it is not known what results it might afford if properly applied to the heads of such comets. Undoubtedly, exposures made in the right manner would afford much valuable data, but it is hardly probable that it would at once enable visual observations to be entirely dispensed with. The case is, in a way, analagous to that of the planets, where photography has, as yet, been of relatively little real service. It is in regard to the tails of comets that the improved photographic plate has demonstrated its superiority to the eye in dealing with questions relating to structure and changes of form. It can grasp what the eye cannot see. It can picture the comet with more detail and with greater truthfulness and accuracy than any artist.

The photographs of the brighter comets which have appeared during the past three or four years have shown, however capricious cometary forms may have been regarded as a result of visual observations, that they have far less stability than had previously been supposed. The changes which take place have the widest range. They may affect any or all parts of the comet, nucleus, coma, and tail. The nucleus may be sharply defined and starlike, or ill-defined, or even indistinguishable from the coma surrounding it; the coma may change in shape, size, and density; envelopes may be thrown out singly or in complex systems; the tail may consist of a single streamer — at least, apparently so,— or of an indefinite number of them; the streamers composing the tail may leave the coma in a single compressed bundle, or they may spring from it in widely divergent and loosely connected groups; they may be smooth, and straight, and distinct, or they may be lumpy, crooked, interlacing, and spirally twisted; or again, they may be broken into fragments, and scattered as though they were as smoke and driven by the wind. The appearance one day affords no indication as to what it may be the next. Conditions and appearances seem to change incessantly. The most radical changes of form have been observed in almost every reasonably bright comet that has been photographed. The changes sometimes take place so rapidly as to become conspicuous in an hour or two. We shall, further on, speak of such a change in the case of RORDAME'S comet, and of some considerations which are suggested by it.



COMET RORDAME, JULY 13, 1893.
$9^h 10^m - 10^h 20^m$ P. S. T.
Photographed by W. J. HUSSEY, at the LICK Observatory.

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THE NUCLEUS AND COMA OF COMET RORDAME.

In the earlier photographs of this comet the nucleus was bright and distinct. It also appeared so in the finder. During the week in which the photographs were taken the coma increased considerably in brightness, and by reason of this the nucleus gradually became obscured. In the later photographs it cannot be seen by examining the negatives with transmitted light. In all cases, however, it can very easily be seen by looking obliquely at the backs of the plates. By reflected light it then presents an appearance very similar to the central point of an over-exposed image of a bright star.

The denser part of the coma was decidedly elliptical in outline during the entire period covered by the photographs — 1893, July 11th to 18th, inclusive. The minor axis was at least approximately coincident with a line drawn through the comet and the Sun. In the reproductions the contrasts are changed to such an extent as to give the coma a very different appearance from that which it has in the original negatives. From measurements of the photographs the following table has been formed, giving

THE DIMENSIONS OF THE DENSER PART OF THE COMA OF RORDAME'S COMET.

DATE, PACIFIC STANDARD TIME.	LENGTH OF EXPOSURE.	MEASURED.		REDUCED.		ECCENTRICITY.
		2a	*2b*	*2a*	*2b*	
1893, July 11^d 9^h 00^m— 9^h 20^m	0^h 20^m	10′.5	8′.4	10′.5	8′.4	.60
12 9 00 —10 12	1 12	12 .6	10 .4	13 .0	10 .8	.56
13 9 00 — 9 6	0 6	9 .8	8 .8	10 .7	9 .6	.44
13 9 10 —10 20	1 10	12 .6	11 .1	13 .9	12 .2	.48
14 8 56 — 9 4	0 8	10 .3	8 .6	11 .8	9 .9	.54
14 9 8 —10 28	1 20	11 .3	9 .6	13 .1	11 .1	.53
15 8 45 — 9 30	0 45	11 .7	10 .0	13 .8	11 .8	.52
16 9 00 —10 00	1 00	9 .6	8 .5	12 .4	10 .9	.48
18 8 48 — 8 56	0 8	5 .9	5 .1	8 .5	7 .3	.51
18 9 1 —10 21	1 20	6 .6	5 .8	9 .5	8 .3	.48

In this table the values *2a*, under the heading "Measured," are the diameters of the coma in a direction perpendicular to the axis of the tail, and the values of *2b* are those in a direction coincident with it. In the next two columns, under the heading "Reduced," these diameters are given reduced to correspond to to the distance of the comet at the time the first photograph was taken, July 11th, 9^h 10^m P. S. T. Assuming the outline of the coma to be an ellipse, the next column gives the eccentricity computed from the values *2a* and *2b* as axes. The times of beginning and end of the exposures are given under the heading "Date." The positions of the comet at the times the photographs were taken were such that differential refraction shortened the diameters *2b* more than the corresponding ones, *2a*. This effect of refraction, having a maximum value less than 0′.1, and being, therefore, considerably less than the uncertainties in the measured diameters, has been neglected in preparing the above table.

It will be noticed that the diameters obtained from the negatives of short exposure are, as might have been expected, materially less than those of long exposure, taken on the same night. From the reduced values, it appears that the dimensions of the coma did not vary much from July 11th to 16th, but that there was a marked decrease between July 16th and 18th. In this interval there was also a marked change in the appearance of the tail near the nucleus. On and preceding July 16th, the tail proceeded from the nucleus in a number of groups of streamers; on July 18th, the streamers formed a single compact bundle at their origin. No photograph was taken on July 17th. On July 18th, the Moon was about five and a half days old, and the illumination of the sky produced by it no doubt tended to extinguish the fainter portions of the outer coma. But, even allowing for this, the change is so considerable that it must be regarded as real.

In some of the other recent comets similar irregular variations have been observed in the diameters of the comas. This was particularly the case with the comets discovered by GALE and HOLMES. In the following table are given the

DIAMETERS OF THE COMA OF GALE'S COMET.

DATE.	DIAMETER OF COMA.	DATE.	DIAMETER OF COMA.
1894, April 5	2′	1894, May 2	12′
23	6	3	18
24	8	5	15
25	10	6	14
26	14	7	13
27	23	8	16
29	15	16	14

These values were published in *Knowledge*, Vol. XVII, page 159, July, 1894. No details are given in connection with them; it is probable that they have not been reduced to a uniform distance. They are the estimates made by Mr. H. C. RUSSELL, Director of the Sydney Observatory. They indicate very large and irregular variations in the diameter of the coma of GALE'S comet, in comparison with which the changes in the dimensions of RORDAME'S comet, while it was under observation, were very slight.

HOLMES' comet is another notable case. Three days after its discovery* it was described by Mr. DENNING† "as a perfectly round mass of nebulosity with a bright central condensation," and with "very definite" edges. While receding from the Earth and from the Sun, it increased in apparent size until its diameter became fully five times as great as at the time of its discovery; at the same time its brightness decreased out of all proportion to the law of inverse squares. Its outline became hazy and indistinct, and a short tail appeared. During the first half of January it continued to grow fainter, and it seemed that it must soon become invisible. On January 16th, however, it was found to have changed suddenly into a bright, hazy, starlike object, having a diameter only one-tenth as great as at the time of discovery. For a few days it remained nearly the same size, but decreased in brightness. It then grew larger and fainter, and finally, in February, disappeared.

In these comets, at least, the changes which took place in the dimensions of the comas were irregular, and did not seem to depend in any way upon the distance from the Sun. This is the more noteworthy in view of the statements to be found in our standard books on astronomy. For example, in YOUNG'S "General Astronomy," an admirable work, page 405, we find the following account:

"It is a very singular fact that the head of a comet continually and regularly changes its diameter as it approaches to and recedes from the Sun; and, what is more singular yet, it *contracts when it approaches the Sun*, instead of expanding, as one would naturally expect it to do under the action of the solar heat. No satisfactory explanation is known. Perhaps the one suggested by Sir JOHN HERSCHEL is as plausible as any,—that the change is optical rather than real; that near the Sun a part of the cometary matter becomes invisible, having been *evaporated*, perhaps, by the solar heat, just as a cloud of fog might be.

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*It was discovered November 6, 1892.

†*Astronomy and Astro-Physics*, Vol. XII, page 371.

"The change is especially conspicuous in ENCKE's comet. When this body first comes into sight, at a distance of about 130,000,000 miles from the Sun, it has a diameter of nearly 300,000 miles. When it is near perihelion, at a distance from the Sun of only 33,000,000 miles, its diameter shrinks to 12,000 or 14,000 miles, the volume then being less than 1-10,000 of what it was when first seen. As it recedes it expands, and resumes its original dimensions. Other comets show a similar, but usually less striking, change."

RORDAME's comet was eleven days past perihelion when its coma was found to have decreased suddenly in diameter. It was seven months after perihelion passage that HOLMES' comet reduced to 29″ in apparent diameter; about a month previously—on Dec. 10, 1892, (*A. and A.-P.*, Vol. XII, p. 32),—its diameter across the nucleus was fully forty times as great. GALE'S comet passed perhelion on April 13, 1894. The table shows that marked and irregular changes in its diameter occurred after that date. These examples are far from confirming the general statement that the head of a comet *regularly* changes its diameter as it recedes from the Sun. Nor do they lend support to HERSCHEL'S suggestion, that the changes are optical rather than real. Their reality is evident, and they incur the suspicion that a more attentive study, even of ENCKE'S well-known comet, might reveal new facts relating to its variations, and they suggest the possibility that these variations may not be as closely related to the distances of the comet from the Sun as has been hitherto supposed.

EXTENSION TO THE COMA OF RORDAME'S COMET.

In all the earlier photographs there is a short and very faint extension to the coma in the position which would be occupied by a tail of the third type, according to BREDICHIN'S theory. Without at present entering into an extended account of this theory, it may be stated that it supposes the tails of this type to consist of matter having considerable density, and from various considerations, to fix ideas, suggests that it may be, and probably is, largely vapor of iron, with an admixture of the vapors of other elements having nearly the same molecular weights. Tails of this type are not of very frequent occurrence, and on this account this faint extension possesses more than ordinary interest. No streamers such as compose the tail proper are observable in it, but their absence may be readily explained. Its shortness and faintness would render them inconspicuous; and, besides, if the particles composing it were in rapid movement,—and there is good reason for believing this to have been the case,—the resulting images would be blurred, and the individual character of the streamers lost. The presence of iron vapor in this comet was not detected by the spectroscopic observations. This, so far as it goes, is an item of negative testimony, but it cannot be regarded as having any considerable weight. This extension was very faint. The radiations from it may have been too feeble to have rendered the characteristic lines of its spectrum visible; and, moreover, the spectroscopic observations were made, not upon it, but upon the coma, and here the continuous spectrum would largely obliterate any very faint lines having their origin by reason of matter such as composed this extension.

THE STREAMERS COMPOSING THE TAIL.

We have already referred to the extent and brightness of the tail of this comet and of the fortunate situation in which it was placed with respect to the line of sight during the time of its greatest brilliancy, rendering it possible to obtain the most satisfactory visual and photographic views of it. We come now to consider some of its photographic peculiarities.

By the photographs, the tail was shown to be composed of numerous streamers, which presented very different appearances on the different nights. Usually a number of groups of them diverge from the central part of the coma and subdivide into many individual streamers before fading away or reaching the end of the tail. The central groups always contain the longest streamers, and the ones which present the greatest number of singularities. The streamers in the outer groups are generally short and straight. In the central groups they are long and often irregular. Sometimes they present a twisted appearance. This was especially the case on the evening of July 18th, when they had very much the appearance of the twisted forms produced by an electrical discharge in a magnetic field.* On this occasion the streamers proceeded from the coma in a single, very compact bundle, from which the separate ones loosened as the distance from the head increased.

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* Some of the photographs of SWIFT'S comet, 1892a, also show a twisted appearance in the tail. (See *Astronomy and Astro-Physics*, Vol. XII, page 205.)

The streamers proceed from the central part of the coma, apparently directly from the nucleus, but it is not possible to be entirely certain concerning this. The late Mr. RANYARD has called attention to this point. In *Knowledge*, September 1, 1894, he says: "The streamers of the tail appear to issue from the center of the nucleus, and not from either side of the envelopes about the comet's head, as the drawings of some of the larger comets would lead one to suppose; but this may possibly be due to irradiation, which causes the bright nucleus and surrounding envelopes of the comet's head to appear larger than they really are." The concurrent testimony of a large number of experienced astronomers as to what they have seen in the case of the great comets leaves no doubt as to the general appearances of the features of these bodies. We may, however, with the best of reasons, conclude that even the most finished drawings which they have furnished us are only sketches, almost wholly wanting in detail and inaccurate in many respects. BOND's many and beautiful drawings of DONATI's Great Comet of 1858, contained in Vol. III of the *Annals of the HARVARD College Observatory*, and DE LA RUE's fine drawings of the Great Comet of 1861, are examples, not to mention many others. These drawings furnish the most convincing proof that in these cases the tail sprung from the envelopes about the nucleus, and not from the nucleus itself. But they show the envelopes and the tail, in general, with a symmetry and smoothness manifestly accordant with the theory of cometary phenomena, and not with that irregularity and abruptness which has become so familiar since the appearance of photography in this line of work. Photographic irradiation has the effect mentioned by Mr. RANYARD, and especially in the case of the photographs of long exposure, such as were sent to him. But the photographs obtained with short exposures are not greatly affected by irradiation, and yet they point to the same conclusion as those of longer exposure. In this connection, it is needless to say that in the study of a point like this the original negatives have an advantage over any of their reproductions.

The groups of streamers are sometimes distinct, and the spaces between them quite free from luminous matter; dark spaces then separate them. These dark spaces are not constant in their positions; they change with the streamers. Sometimes

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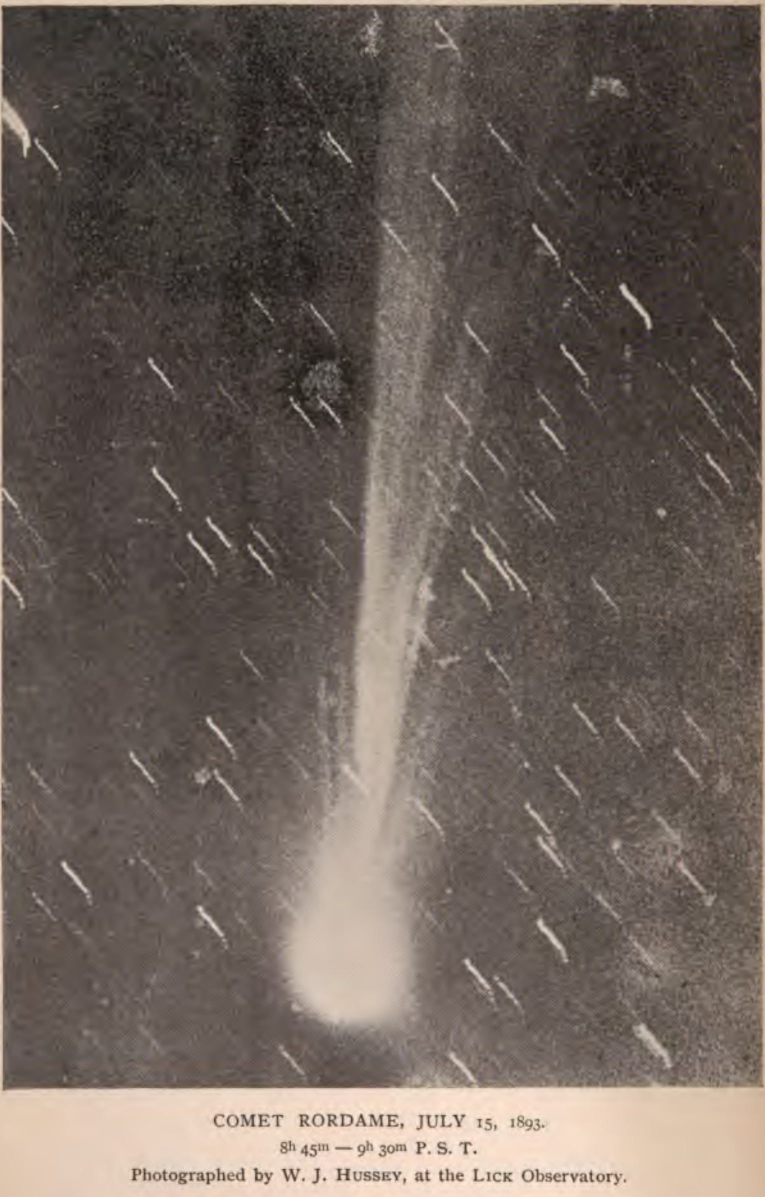

COMET RORDAME, JULY 15, 1893.

$8^h\ 45^m$ — $9^h\ 30^m$ P. S. T.

Photographed by W. J. HUSSEY, at the LICK Observatory.

they make a considerable angle with the general axis of the comet's tail, and at others they nearly coincide with it. According to the commonly accepted theory of the formation of the tails of comets, matter in an attentuated state is driven from the head of the comet by a repulsive force, and it is also subjected to the action of a repulsive force from the Sun, which drives it backward from the tail. The orderly development of a comet's tail, in accordance with this hypothesis, would lead to a figure more or less curved, having somewhat the appearance of what may be called a hollow curved cone, and it would be brighter near the edges than in the center along the axis of the tail. Many visual observations attest to appearances of this kind; but the photographs of RORDAME'S comet give very little, if any, realization of such a conical form, and these photographs are in this respect, I believe, entirely in accord with all the others which have been obtained of recent comets. The individual streamers cannot be seen by visual observations, and even the groups of them blend together to such an extent that they cannot generally be clearly distinguished. As a consequence of this, the dark space between two principal groups of streamers will in the case of the smaller comets, by being imperfectly seen, give the tail a hollow appearance, and, even with the comets of largest size, something of this effect will be produced. It would be highly interesting to know to what extent the hollow appearance of the tails of the great comets is due to this cause. It is, however, far from probable that it alone affords an adequate explanation.

CONDENSATIONS IN THE TAIL.

Among the conspicuous features exhibited in some of the photographs of recent comets are masses of luminous or illuminated matter constituting a part of the tail. They have been called *condensations*. They have occasionally been seen visually in the great comets, but such observations have been very rare. They were beautifully photographed by Professor BARNARD in SWIFT'S comet, in April, 1892, and in BROOKS' comet, in October, 1893. They were very conspicuous in some of my photographs of RORDAME'S comet, and are to be found in others. Condensations have also been photographed by several other astronomers at other observatories.

They are not constant features. They may be visible one day and invisible the next. They were conspicuous at times in the comets named above, three of the brightest of which have appeared during the past three years. This indicates that they are not exceptional among cometary features, and suggests not only the possibility of their being more or less constantly present in those of the largest class. It is not unreasonable to suppose that they are simply the more dense aggregations of the matter which constitutes the tail, and that the streamers themselves would in all cases be found to consist of similar but less pronounced aggregations, if they could be observed under circumstances sufficiently favorable. That they have not been observed more frequently is to be attributed to the circumstances of their position and to inadequate means of observation.

THEORY OF COMET TAILS.

It is stated above that, according to the commonly accepted theory of the formation of the tails of comets, matter in an attenuated state is driven from the head of the comet by a repulsive force, and is also subjected to the action of a repulsive force emanating in the Sun, which drives it backward to form the tail. This theory has been brought to a high degree of perfection by the successive labors of many astronomers, particularly OLBERS, BESSEL, NORTON, and BREDICHIN. OLBERS' investigations* were incited by the phenomena of the Great Comet of 1811; BESSEL'S† by those of HALLEY'S comet on its return, in 1835; NORTON'S‡ by DONATI'S comet, in 1858, and COGGIE'S, in 1874. BREDICHIN'S investigations§ have included a careful study of a large number of comets.

According to this theory, the shape and position of the tail depend upon the motion of the comet and the effective intensity of the repulsive force. And, consequently, given the motion of the comet and the shape and position of its tail, it becomes possible to compute the effective intensity of the repulsive force. But the mode of action of this force enters into its expression, and we approach the unknown. We do not know absolutely the manner of its variation, whether it varies as the mass, or surface of the particle repelled, or how. There are many considerations which favor the view that the force is a case of electrical repul-

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**Monatliche Correspondenz*, Vol. XXV, page 3.

†*Astronomische Nachrichten*, Bd. 13.

‡*American Journal of Science*, 2d Ser., Vol. 29, page 383, Vol. 32, page 54, and 3d Ser., Vol. 15, page 161.

§*Annales de l'Observatoire de Moscou.*

sion. This is the usual assumption. If this is the case, there is a surface action, the force being the same for equal surfaces of any kind of matter. This is equivalent to assuming the effective accelerating force to be proportional to the molecular weights of the substances moved, and a force acting in this way would produce different effects, according to the kind of matter upon which it acts. The matter having the least molecular weight would be driven most directly away from the Sun, the heaviest would trail along near the path of the comet, and that of intermediate weight would stream out in curves situated intermediate between these two positions. Thus the position of a comet's tail would become an index of the material composing it, and multiplicity of tails would indicate a complex chemical constitution.

From a study of the forms of a large number of comets, BREDICHIN has arrived at the following classification of their tails into three types:

I. Tails which are very straight and directed very exactly away from the Sun.

II. Tails which are considerably curved, being convex towards the direction of motion.

III. Tails which are short and strongly curved, situated almost in the path of the comet.

From a consideration of the ratios of the molecular weights of the various elements which the spectroscope has shown to exist in comets, he suggests, to fix ideas, that the tails of the first type may consist of hydrogen, those of the second type of hydrocarbon compounds, and those of the third type of heavy metallic vapors, such as iron, etc.

From the preceding statements it appears that the formation of a comet's tail depends upon a number of heterogeneous elements; the chemical constitution and physical condition of the matter composing the tail, as well as the nature of the repulsive force, and the geometrical form of the tail are all bound together by mutual relations. The spectroscope furnishes some information concerning the chemical constitution of these bodies; laboratory investigations on meteorites may furnish more; by photography the form and position of the tail may be accurately determined. But even with all this, not enough is known. From an analytical standpoint there are still a larger number of unknown quantities than there are equations of condition, and the solutions are, therefore, indeterminate. Something more comet. If the condensations were clearly defined, it would be easy to measure their distances from the nucleus in the two negatives, and then to calculate their rate of recession from it. With these negatives it is not possible to make the necessary measurements with very satisfactory exactness. The nucleus is practically concealed in the photographs by the dense coma surrounding it. The rapid relative motions of the condensations caused them to be photographed as trails, thus giving blurred images; and, moreover, this effect is not present to the same extent in the two negatives, on account of the disparity in the times of exposure. On these accounts it is impossible to determine the exact points upon which the measurements should be made, and the results are correspondingly uncertain. This uncertainty would be materially decreased if the negatives were of equal exposure, and that of only sufficient duration to give distinct images of the condensations.

Measurements have been made on three condensations situated at distances of 1°.87, 3°.66, and 5°.88 from the nucleus, giving respectively velocities of forty-four, fifty-two, and fifty-nine miles a second. In the computation of these velocities the effect of projection and of the difference of differential refraction have been included. The second condensation is more determinate than the others, and its velocity is, therefore, entitled to a greater degree of confidence.

The lowest of these velocities corresponds to nearly 4,000,000 and the highest to somewhat more than 5,000,000 miles a day. Enormous as these velocities are, they do not exceed those which are to be expected from the consideration of certain cometary phenomena. For example, the rapid changes in the direction of their tails at the time of perihelion passage and the sudden changes in the forms of the tails predicate enormous velocities.

Such velocities as those stated above are highly significant. They must be taken into account in considering the remarkable changes which take place in the forms of the tails of comets as exhibited by their photographs. On their account the photographs are to a certain extent inaccurate and misleading. During the time of exposure, and especially in the case of a long one, the condensations, and very likely all the other forms which [illegible] to make up the tail, move an appreciable angular distance, and are consequently photographed as trails. This is a result that must be added by observation before this tangle of complex relations can be unraveled. Any independent data connecting the unknown quantities will be useful. The velocities with which the particles composing the tail recede from the head, if they can be obtained with sufficient accuracy, will enable a long step in the right direction to be taken. Two methods of obtaining these velocities suggest themselves; first, by measuring the motion in the line of sight spectroscopically, a thing which may be possible in the case of very bright comets, and, second, by measuring the displacements on a series of photographs taken with proper exposures and at short intervals of time. From some of the results already obtained by photography, it is highly probable that we now possess sufficient means to enable these velocities to be obtained, at least in the case of the brighter comets. In SWIFT'S comet, 1892, it was noted* that the condensations were receding from the head at a measurable rate, and it has been possible to make approximate estimates of the rate of

MOTION OF CONDENSATIONS IN RORDAME'S COMET.

On the evening of July 13, 1893, I obtained three photographs of RORDAME'S comet, two of which were taken with the CROCKER telescope—one with an exposure of six minutes (from $9^h\ 0^m$ to $9^h\ 6^m$), and the other of seventy minutes (from $9^h\ 10^m$ to $10^h\ 20^m$), P. S. T.

These negatives show the same condensations; on account of the short interval between the exposures, there can be no mistake of identification.† By a comparison of the position of the condensations in reference to the nucleus, it is easy to see that they are not fixed, but in rapid motion away from the head of the comet. If the condensations were clearly defined, it would be easy to measure their distances from the nucleus in the two negatives, and then to calculate their rate of recession from it. With these negatives it is not possible to make the necessary measurements with very satisfactory exactness. The nucleus is practically concealed in the photographs by the dense coma surrounding it. The rapid relative motions of the condensations caused them to be photographed as trails, thus giving blurred images; and, moreover, this effect is not present to the same extent in the two negatives, on account of the disparity in the times of exposure. On these accounts it is impossible to determine the exact points upon which the measurements should be made, and the results are correspondingly uncertain. This uncertainty would be materially decreased if the negatives were of equal exposure, and that of only sufficient duration to give distinct images of the condensations.

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* SWIFT'S Comet (a 1892). By A. E. DOUGLASS, *Astronomy and Astro-Physics*, Vol. XII, page 202.

† In *Astronomy and Astro-Physics*, Vol. XII, page 203, Mr. DOUGLASS states, in his article on SWIFT'S comet: "For purposes of measuring the velocity of recession from the head, eight points were identified, each point being found upon two plates, and their distances from the nucleus were determined. They may be subject to small errors, owing to the hazy outlines of the comet itself. Nevertheless, one case is subject to no uncertainty. It occurs on the plates of April 7th and 8th, when a slender, curved stem connects the head with a conspicuous and well defined luminous mass at the base of the main tail."

I do not understand this statement. It is not clear to me whether the "one case" which "is subject to no uncertainty" refers to the *measurements of velocity* or to the *identification of condensations*. If the latter is meant, it would seem that the most certain identification of condensations made by Mr. DOUGLASS depends upon a comparison of plates of different dates—April 7th and 8th. *Such an identification would be extremely uncertain*, and, in the present state of our knowledge, would have no value, unless confirmed by the plates taken between the two dates, thus forming a practically continuous record.

Measurements have been made on three condensations situated at distances of 1°.87, 3°.66, and 5°.88 from the nucleus, giving respectively velocities of forty-four, fifty-two, and fifty-nine miles a second. In the computation of these velocities the effect of projection and of the difference of differential refraction have been included. The second condensation is more determinate than the others, and its velocity is, therefore, entitled to a greater degree of confidence.

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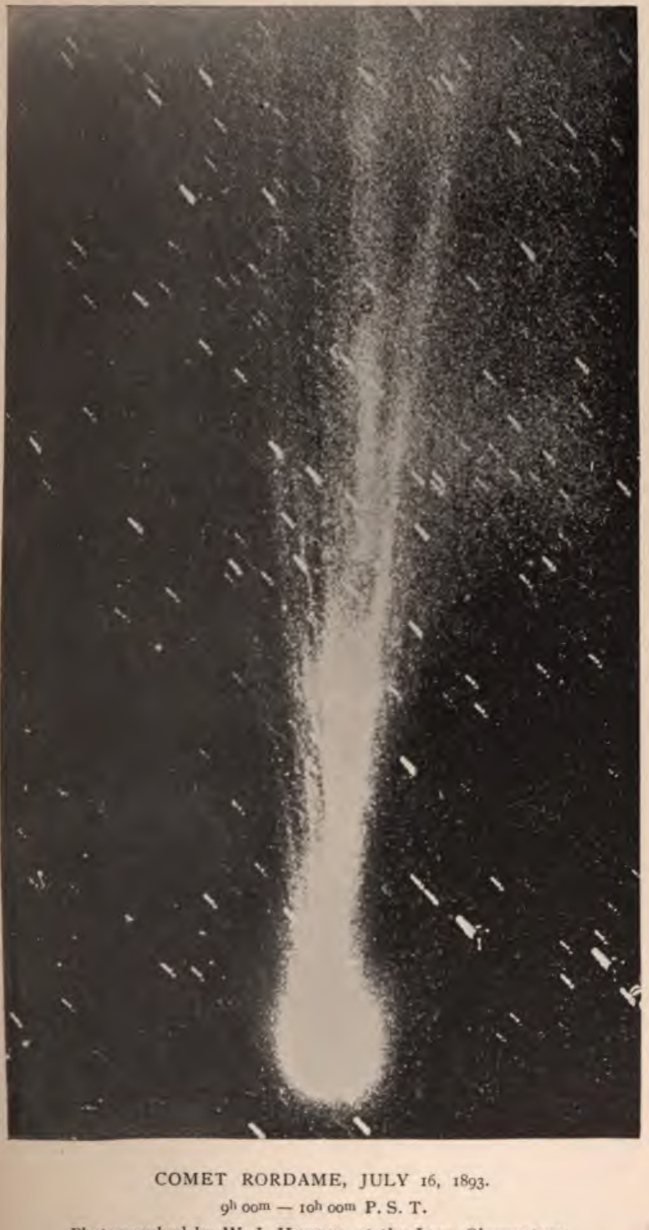
Such velocities as those stated above are highly significant. They must be taken into account in considering the remarkable changes which take place in the forms of the tails of comets as exhibited by their photographs. On their account the photographs are to a certain extent inaccurate and misleading. During the time of exposure, and especially in the case of a long one, the condensations, and very likely all the other forms which go to make up the tail, move an appreciable angular distance, and are consequently photographed as trails. This is a result that is inevitable. It cannot be wholly overcome by any change in the manner of using the telescope. Exposures of short duration will avoid a part of the difficulty, by making the trails shorter, but another and perhaps more serious difficulty will be introduced. With short exposures, the negatives will be thin, wanting in detail, and generally unsatisfactory. The only practical course is to keep in view the probable velocities of motion and to allow for their effect in the interpretation of the photographs.

In consequence of their motions, the condensations trail and their photographic representations are blurred and indistinct. Details relating to form are lost, dimensions in the direction of motion exaggerated, and intensities correspondingly diminished. The fainter condensations fail to make a definite impression; they are blended with the streamers, and the streamers are blurred and intensified by them. Photographs of short exposure naturally show the condensations nearly in their true proportions, and from such photographs it appears, in the case of RORDAME'S comet, that they are generally not of large dimensions. Their trailing satisfactorily explains why they are so conspicuous in the photographs of long exposure and at the same time invisible to the eye.

In RORDAME'S comet the condensations were moving with an accelerated velocity. This is in accordance with cometary theory. Even at the measured velocities, the condensations would have traversed a distance equal to the length of the brighter portion of the tail in less than a day. It seems probable that those observed on July 13th traversed the entire length of the tail, or had become entirely dissipated in less than this time. They are not to be found on the photograph of the preceding night, nor on those of the following night.

If like velocities can be established in the case of other comets, it is evident from the preceding paragraph that the streamers and condensations which form the tail one day cannot be assumed to be the same as those which form it on the next. To establish the identity of condensations, streamers, and groups of streamers, observed on successive days, requires either a practically continuous record for the intervening time or a tolerably complete acquaintance with the laws of force in accordance with which the changes take place. Neither of these requirements have been sufficiently supplied. Notwithstanding the manifold labors of many eminent astronomers, cometary theory has not yet reached that stage of



COMET RORDAME, JULY 16, 1893.

$9^h\ 00^m$ — $10^h\ 00^m$ P. S. T.

Photographed by W. J. HUSSEY, at the LICK Observatory.

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ASTOR, LENOX AND
TILDEN FOUNDATIONS.

its development which enables us to account for the capricious changes which have been so many times observed. No complete photographic record has been obtained of any comet, and, manifestly, it cannot be obtained by the work of a single observatory. That we should have such a record of the important comets which are favorably situated for photographic observation is a desideratum.

THE QUESTION OF ROTATION.

The considerations of the last paragraphs have an important bearing on the general question of the rotation of the heads of comets. It is very natural that this question should have arisen, and that there should be numerous references to it in the cometic literature of this century. In no comet has rotation been clearly established. BREDICHIN summarily disposes of that part of DUNLOP'S observations of the Comet of 1825, IV, "On the changes which take place in the figure of the tail, tending to establish the existence of a rotation round its axis,"[*] by saying, "these attempts have no value, and only show that DUNLOP, although a skillful observer, had very little acquaintance with the principles of mechanics."

BESSEL carefully considered the phenomena of HALLEY'S comet on its return in 1835,[†] and found the evidence somewhat more largely in favor of rotation about an axis lying in the plane of the orbit than about one perpendicular to this plane. These researches of BESSEL form an interesting section of his classic memoir, but they cannot be regarded as having proved or disproved the rotation of the head of this celebrated comet.

NORTON'S investigations in this direction were incited by the "columnar structure[‡] of the tail" of DONATI'S comet. In this connection he says:[§] "An interesting result of the investigation is that the alternate bright and dark bands so distinctly seen to traverse a certain portion of the tail of DONATI'S comet, in nearly parallel directions, on the evening of October 10th, had each the position of the line connecting particles which started from the region of the nucleus at a certain previous date and at the same instant of time. They accordingly find their natural explanation in corresponding alternations in the quantity of nebulous matter given off simultaneously from the nucleus. The most probable cause of such alternations of discharge that can be conjectured is that the nucleus turns about an axis, and so presents periodically different sides to the Sun, which were unequally influenced by his inciting action. If this be the true explanation of the phenomenon, we have in the observed distance between contiguous bright bands the means of determining the period of rotation; or, at least, the shortest interval of time in which the rotation can be completed. If we take these distances at 1°, the period of rotation comes out twenty-four hours."

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[*] BREWSTER'S *Edinburgh Journal of Science*, 1827; *Annales de l'Observatoire de Moscou*, Vol. VIII, 1, pages 86 and 95.

[†] *Astronomische Nachrichten*, Bd. 13.

[‡] According to BOND, the observations on the "columnar structure of the tail" of DONATI'S comet were quite discordant. (*Annals of the Obseraatory of* HARVARD *College*, Vol. III.)

[§] *American Journal of Science*, 2d Ser., Vol. 29, page 81.

The photographs of recent comets afford illustrative material which renders it very probable that the alternation of bright and dark bands which produced the columnar structure in the tail of DONATI'S comet were nothing else than streamers of extraordinary brightness and the dark spaces between them. This is rendered the more probable by the fact that the streamers, as shown by the photographs, sometimes lie obliquely to the axis of the tail, as was the case with the bands observed in DONATI'S comet. On this account we are inclined to regard them in a somewhat different light from that in which NORTON viewed them, in so far, at least, that instead of each streamer being composed of particles which left the region of the nucleus at the same instant of time, that it must have been composed of those leaving that region at very different times. If we accept the streamers as affording an explanation of the banded or columnar appearance of the tail, we at once remove not only the basis of Professor NORTON'S calculation of the period of rotation, but also, as far as can be judged from the records of the phenomena of these streamers, *nearly* all evidence whatever of rotation.

Professor BARNARD has recently remarked the changes in the relative brightness of the component parts of SWIFT'S comet, as shown by its photographs, and states that it "would almost suggest a rotation of the tail about an axis through the nucleus."* The well-known rapid changes in the appearance and positions of the streamers and the entire absence of definite knowledge as to the order in which these changes occur, and of the conditions producing them, forbid us hastily assuming changes of brightness as indications of rotation. The changes in the positions of the streamers, if they should be continuously observed, might possibly afford undoubted evidences of rotation and the data by means of which the period could be deduced, but it does not seem at all probable that this can be done from photographs taken at intervals of twenty-four hours or more.

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* *Astronomy and Astro-Physics*, Vol. XI, page 338

If the head of a comet is a rotating body, the streamers emanating from it will have their forms in space determined by the circumstances of their projection and of the rotation. It is easy to see that the form of a streamer emanating from a given point in the head of a rotating comet will, in general, be a spiral of double curvature; the orbits, however, of the individual particles composing the streamer being hyperbolas. In some photographs there is abundant evidence of such spiral motion, especially in the case of streamers which issue from the center of the comet's head, and form the central portions of its tail. If the twisting of the streamers be taken as evidence of rotation, which may be a rather hazardous assumption in the present state of our knowledge, it will be necessary to explain why some are twisted and others are not in the same photograph, and why the twisting is more extensive on some occasions than on others.

If we assume that the head of a comet, or, at least, the denser portion of it, is merely a large aggregation of meteoroids with their attendant atmospheres, and, further, that the meteoroids are not uniformly distributed, but grouped in "swarms," it will not be difficult to imagine such conditions of revolution as would fully account for most, if not all, of the individual peculiarities of the streamers and groups of streamers, and, at the same time, be free from requiring a permanency in their forms and positions. In this case, however, we should not have a rotation of the comet, but revolution of its component swarms of meteoroids.

CURVED AND BROKEN STREAMERS; ENCOUNTER WITH EXTRANEOUS MATTER.

An interesting phenomenon is the congruent bending of adjacent groups of streamers, it being often the case that a deflection in the components of one group is accompanied by a corresponding deflection of nearly equal magnitude in an adjacent one. This sometimes occurs in places where the groups of streamers are widely separated by clear spaces and at great distances from their common origin.

More or less abrupt bends also occur in single groups of streamers. These, of course, are the more conspicuous when they occur in the larger groups. The principal group in the tail of SWIFT'S comet, on April 6, 1892,* was abruptly bent near the comet's head. Several similar bends occurred in the larger groups of streamers in the tail of RORDAME'S comet, on July 15, 1893.

At times, there are also breaks in the streamers. One of the principal groups in RORDAME'S comet, on July 12, 1893, was nearly discontinuous within a degree of the nucleus; nearer and further from the nucleus this group was strong. Extreme confusion reigned in BROOKS' comet, on October 21 and 22, 1893. On the first of these dates, the tail as a whole was curved in an unusual manner, being roughly sinuous, and, therefore, standing in marked contrast to that form which cometary theory prescribes; *condensations were numerous* and the streamers generally were much disturbed and confused. On the 22d, the tail was nearly straight; it was also very much shattered, one fragment being entirely detached. Professor BARNARD'S photographs of this comet for these dates are reproduced in *Knowledge*, February and May, 1894. In his account of his photographs he says:

"The tail now [October 21st] presented the aspect of a torch streaming in the wind. The appearance was precisely what we should expect had the comet's tail, in its flight through space swept across or through some medium dense enough to break up the tail. I cannot see how any one, comparing this with the picture of the 20th, can escape the conclusion that the tail did actually encounter a disturbing medium which shattered it. This theory is, I think, further upheld by the third of these pictures taken on the following morning [October 22d], where the tail hangs in cloudy masses, like the broken train from a locomotive. In the last picture a large fragment is actually torn off and completely separated from the end of the tail. In the second photograph [October 21st] the entire comet was brighter, as if the disturbance had added to its light, as also seems to have been the case with the third photograph, on October 22d; for its exposure was much shorter, as flying clouds were obscuring the sky a considerable portion of the time."

The view presented in this quotation has, naturally enough, not passed without criticism. As Mr. HARRY PROCTER says,* it is "more probable that the irregularities in the tail are due to irregularities in the quantity of matter streaming away from the nucleus, as well as due to changes in the direction in which the streams of matter are driven forth from the head of the comet," than that they are due to the resistance of extraneous bodies. It is undeniably true that the matter composing the tail of a comet is often emitted in an irregular manner. There is the amplest evidence of this in the photographs of recent comets. The existence of condensations proves it. It is also true that the streams of matter composing the tail proceed from the comet's head in very different directions at different times; moreover, they change with a rapidity which renders it impossible to identify with certainty those of one day with those of the next. The photographs also afford ample evidence of this. With these facts in mind, it is not difficult to imagine such variations in the quantity of matter emitted from the comet's head, and of such differences in the directions of emission at different times, to account fully for all those peculiarities in the forms of the tails of comets which have given rise to the doctrine of an encounter of the comet with a disturbing medium — a doctrine which, it is needless to say, has very little in its favor.

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* Professor BARNARD'S photograph of this comet for this date has been published in *Knowledge*, Dec. 1892, and in third edition of CLERKE'S *History of Astronomy During the Nineteenth Century*.

LELAND STANFORD JR. UNIVERSITY, May 27, 1895.

ADDENDUM.

After the foregoing article was in the hands of the printer, I received from Dr. BREDICHIN his paper entitled "*Mouvement des substances émises par les comètes,* 1893, II, *et* 1893, IV.†

The portion of his paper devoted to comet 1893, II (comet RORDAME), is based upon a letter that I sent him, January 28, 1895, as follows:

"You may be pleased to know that from a study of some of the photographs which I obtained of Comet RORDAME, I have been able to determine approximately the rate at which 'condensations' in the tail are receding from the nucleus. On July 13, 1893, G. M. T., about seventeen hours, a condensation of 3°.7 from the nucleus was receding at an hourly rate of not less than 400,000 miles.

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* *Knowledge*, March, 1894, p. 63.

† *Bulletin de l'Académie Impériale des Sciences de St. Pétersbourg* (May, 1895).

"I have a paper in preparation, which will be published shortly, and I shall be pleased to send you a copy when it is ready."

I hasten to express my sincerest regret that this letter furnished Dr. Bredichin an incorrect datum; the velocity given in it is too large. The error was introduced in the calculation by two figures being inadvertently interchanged. With the velocities given in the foregoing paper, which, it is believed, are near the true ones, the results are much more nearly in accordance with those prescribed by cometary theory, being approximately twenty-five per cent. larger than we should expect for hydrogen — the element having the lowest known molecular weight.

The velocities given in the foregoing paper have been derived from measurements of the original negatives. These measurements were made on the measuring engine belonging to the Lick Observatory. On each of the two negatives of July 13, 1893, the distances from the nucleus to the condensations situated at 1°.87, 3°.66 and 5°.88 from it, were measured, and the differences of the results taken. These differences are 0.062, 0.071 and 0.081 inches respectively. These differences represent the motion of the condensations away from the nucleus in the mean interval between the exposures. This interval is forty-two minutes, the middle of the first exposure being $9^h\ 3^m$, and of the second, $9^h\ 45^m$, P. S. T.

From measurements of photographs of the stars, I have found the equivalent focal length of the Crocker telescope to be 30.82 inches. The scale of the photographs is, accordingly, one inch = 1°.86. The distances 0.062, 0.071 and 0.081 inches correspond, therefore, to angular movements of 415″, 475″ and 542″, respectively. These values are too small, on account of being affected by the difference of differential refraction for the times of the two exposures. On this account, they must, respectively, be increased by 34″, 48″ and 54″, giving 449″, 523″ and 596″.

The comet's distance from the Earth was 44,377,000 miles — the logarithm of its distance in astronomical units being 9.67916. The tail of the comet was straight, and I have assumed that it coincided with a line through the Sun and the nucleus of the comet. This line, at the time under consideration, made an angle of 60° 10′ with the line of sight.

With these data, the velocities which I have obtained for the three condensations are 44.2, 51.5 and 58.7 miles per second; or, expressed in astronomical units, the mean distance of the Earth from the Sun being the unit of distance, and 58.13244 mean solar days the unit of time, they are, respectively, 2.389, 2.783 and 3.171.

The theoretical velocity for tails of the first type, for the position of the second condensation, is 2.27, instead of 2.78 as given above.

As has been previously stated, the second condensation was more determinate than the others, and its velocity is accordingly entitled to a greater degree of confidence. Its velocity may be somewhat too small. I do not think it is too large.

Dr. BREDICHIN, assuming the velocity I sent him—400,000 miles an hour,—has computed the corresponding value of $1 - \mu$, and obtained 247. In this μ is the effective acceleration of the Sun at the unit of distance. From his previous investigations, the definitive value* of $1 - \mu$, for tails of the first type—which are supposed to consist of hydrogen—is 17.5.

With the same data that he used, but with the velocity given in this paper, I have found $1 - \mu$ to be 36, or about twice as great as for the first type. According to Dr. BREDICHIN'S theory, this value of $1 - \mu$ corresponds to a substance having a molecular weight only half as great as hydrogen.

June 22, 1895.

DESCRIPTION OF A NEW CASSEGRAINIAN TELESCOPE, EQUATORIALLY MOUNTED, HAVING AN EQUIVALENT FOCAL LENGTH OF TWO HUNDRED AND FIFTY FEET.

By J. M. SCHAEBERLE.

For obtaining the best astronomical photographs, the reflecting telescope should possess a great advantage over the refractor, for only by reflection can all the rays—both visible and invisible—of the spectrum, coming from a celestial object, be brought to a common focus.

With one or two exceptions, but little has been done in the photography of celestial objects having very small angular dimensions.

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* *Annales de l'Observatoire de Moscou*, 2d Series, Vol. I, 1, page 22.

The photographs of *Jupiter*, taken with the great refractor of the LICK Observatory, and those of *Saturn*, taken with the Paris refractor, are of real merit, and probably represent the best results in this line so far obtained by astronomers.

In photographs taken with the refractor, the minuteness of the planetary (and similar) focal images, and the inherent defects of these images, due to the dispersion of the rays, will always tend to obliterate the details seen visually. These optical defects are still further increased when such focal images are enlarged in the telescope by means of lenses. For the enlarged image, the same defects, though in a much less degree, will exist when the focal image is formed by a reflecting surface and the enlargement secured by means of lenses.

Some preliminary experiments during the past winter and spring made it evident that there were no good reasons why the enlarged focal image should not be wholly made by reflection, thus doing away with the inevitable dispersion of the rays caused by the use of lenses.

In the Cassegrainian (or Gregorian) form of telescopes, the size of the focal image after reflection from the secondary mirror can be increased to any desired linear dimensions by simply bringing the secondary mirror to the required surface curvature.

During the early days of my connection with the University of Michigan, I ground, polished, and figured a number of disks of glass, to be used as parabolic reflectors. Three of these are at present at the LICK Observatory. They have the following constants:

Aperture.	Focal Length.
8 inches.	6 feet.
12 "	4 "
18 "	12 "

All of these were mounted, at Ann Arbor, as Newtonians, on home-made equatorials; but owing to the great amount of teaching in the University of Michigan, my time was so fully occupied that no systematic work was possible with these instruments.

In order to take full advantage of this method of securing very large celestial images to be photographed in the telescope without the use of lenses, the following conditions, at least, must be fulfilled:

1. The reflecting surfaces must be of unusually perfect curvature.
2. The mounting must be equatorial, very rigid, and the form either Cassegrainian or Gregorian.
3. The driving-clock must have no short periodic variations of rate.

The eighteen-inch reflector was originally intended to be used as a Newtonian. To adapt it to the Cassegrainian form, it was necessary to cut out the central portions of the mirror. While there was considerable danger that the figure of the mirror might be altered, I nevertheless took the risk, as there was but little probability that the reflector would be used as a Newtonian at the LICK Observatory. Accordingly, a concentric disk of the reflector, something over four inches in diameter, was cut directly from the central area of the mirror by means of a cylinder of thin sheet-copper, the saw-toothed grinding edge of which was kept supplied with emery and water. The tool was held in a foot-lathe chuck, revolving several hundred turns per minute, while the reflector was vertically mounted in a stationary frame, which could be pressed against the grinding tool.

An immediate test of the mirror after the removal of the central disk showed that no sensible alteration of the figure had taken place.

As the only practical way to bring the secondary mirror to the proper figure is by actual trial on celestial objects, it was essential, first of all, to have the large mirror mounted equatorially. In designing the form of mounting, great rigidity of all the parts was constantly kept in view.

The thirteen-foot tube is made of half-inch boards, bound with iron. It is supported below its center (by two opposite bearings, which form the declination axis,) in a rectangular iron frame, or cradle, so that it can swing through an arc of 140°. This cradle, in turn, is supported by two other bearings, which form the hour-axis of the telescope after the plan of the old English mountings.

The upper pivot of the hour-axis is four inches in diameter, and rests in a brass Y fastened to the top of a rigid triangular wooden frame, which is inclined to the horizon at an angle equal to the co-latitude of the place. The lower pivot is only three-quarters of an inch in diameter. It revolves in a steel bearing, and abuts against a brass plate, which takes up the end thrust.

Near the upper end of the tube are two opposite bearings, in which swings an iron fork, the handle of which passes through and can be clamped (in Declination) to a collar in the hour-axis at the lower interior side of the cradle.

The diurnal motion is secured by means of a governing-clock, acting on a 15° sector of nearly ten feet radius. This sector is fastened to the outer end of a trussed iron frame, one of whose legs encircles the upper pivot of the hour-axis, while the lower pivot of the hour-axis passes through the lower leg of this sector-frame. The tube is clamped (in Right Ascension) to the sector by means of an iron rod (pipe) which turns in a ball-and-socket joint on the west axis of the declination fork. Near the joint this rod is bent through an angle of about 30°, so that the inclination of the rod to the tube can be varied through an angle of 180°. This rod runs through and can be clamped to a collar on the sector-frame near its outer extremity. The action of gravity on the sector-frame is the motive power for running the clock.

For large western hour-angles a shorter rod is screwed into the ball portion of the joint, in place of the longer rod.

The advantages of this form of mounting are:

First.—The upper and lower ends of the hour-axis are mounted on separate piers, thus giving great stability to the axis.

Second.—The moving tube is continually supported and braced in five different directions, viz.: the two supports forming the declination axis, the two supports given by the fork for clamping in declination, and the right ascension rod running to the sector.

Third.—The great radius of the sector diminishes the errors due to irregularities in the running of the clock.

The driving-clock forms part of one of the LICK Observatory chronographs, and was placed at my disposal by Professor HOLDEN.

For experimenting, a number of ordinary double convex lenses, about four inches in diameter, and having focal lengths of from one to twelve feet, were procured. All of these surfaces gave, by reflection, either blurred, distorted, or multiple images when placed in the best position on the axis of the eighteen-inch mirror used as a Cassegrainian. In the work of refiguring the surface of one of these lenses, which gave an equivalent focal length of about eighty feet, I found it indispensable to have some convenient and rapid means for adjusting both the large and secondary mirrors. Accordingly, three longitudinal slots were cut in the tube, through which the three thin steel blades which support the secondary mirror project. These are fastened to wooden rods which run to the eye-end of the tube, where, by simply turning a hand-wheel, a slow motion towards or from the observer can be given to any one of the three supports of the secondary mirror.

The pan containing the large mirror is supported at three equidistant points by thumb-screws which pass through the lower (closed) end of the tube. By turning these screws the inclination of the large mirror can be changed at will.

The first surface figured required many hours of local polishing, the mirror (secondary) being tested on celestial objects at intervals, until the rays reflected from the large mirror were all brought to the same focus. To test the photographic advantages of this system, one of the most difficult of the celestial objects, giving the finest details for testing—the planet *Saturn*, —was photographed, with exposures varying from 1ˢ to 15ˢ. The character of the results obtained at once showed that much larger images than those corresponding to a focal length of eighty feet could be advantageously photographed.

Accordingly, I at once commenced correcting another surface which gives an approximate focal length of 250 feet. Patient polishing and repeated testing in the telescope resulted in a surface which gives even better images than the first one figured. The surfaces were all silvered by FOUCAULT'S process.

On the trial negatives *Saturn's* outer ring is something over six-tenths of an inch in diameter. The difference in brightness of the outer and inner rings, the shadow of the planet on the rings, the shadow of the ring on the planet, the crape ring, the belts on the planet, are all shown on the photographs.* At present the instrument is mounted in the open air, so that, in spite of the rigidity of the parts, the effect of the wind, plainly seen in the slightly shifting image on the ground glass, is such that the best results can only be expected after the instrument is inclosed in a building. Until this is done it is inadvisable to make another secondary reflector giving still larger images.

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* Some of these trial photographs were exhibited at the meeting.

I hope in a future number to give some photographic illustrations of celestial objects taken with this instrument, together with a view of this telescope.

With this particular mounting, the observations are restricted to objects having less than 70° declination. There is, however, no reason why the same form of mounting should not be used for all declinations; for, by simply lengthening the cradle in which the telescope swings to a little more than one-half of the length of the tube, the desired end is obtained.

Since the work on this telescope was commenced, a number of articles (by Mr. COMMON and others) have appeared, on what has been called a *skew* Cassegrainian telescope. It is safe to say that no large reflector used in this way will ever give as good results for full aperture as it would with its axis coinciding with the optical axis of the telescope. In the April number of the *Monthly Notices* of the Royal Astronomical Society, one observer (Mr. BROOKS) goes so far as to say: "I would here call attention to the fact that the correction of distortion caused by the tilting of the large speculum can be corrected by the proper tilting of the small flat mirror, as well as if it were convex." Now, it can easily be demonstrated that the image reflected from a plane mirror will have precisely the same form (neglecting reversals) as that which would be formed if the rays were allowed to come to a focus without secondary reflection; that is, the form of the image remains unchanged whatever the inclination of the plane mirror may be. A distorted image cannot be corrected by reflection from a plane surface; and it would seem that only by a happy accident could the distorted image from a large surface be completely corrected by reflection from a second curved surface.

I wish to state that this telescope was practically finished before Mr. CROSSLEY presented his great reflector to the LICK Observatory—a rather fortunate circumstance, for otherwise I should probably not have felt sufficiently encouraged to undertake the work of constructing the present instrument. With the exception of the clock, all the work was done by individuals connected with the LICK Observatory. Mr. MACDONALD, our foreman of the Observatory employees, and Mr. BANE, our carpenter, were especially active and efficient. Professor HOLDEN placed the resources of the Observatory at my disposal.

VARIATIONS OF TERRESTRIAL LATITUDES, ETC.—REPORT OF THE WATSON TRUSTEES ON THE AWARD OF THE WATSON MEDAL OF THE NATIONAL ACADEMY OF SCIENCES TO DR. S. C. CHANDLER.

By S. Newcomb, B. A. Gould, A. Hall.

[The following paragraphs are extracted from the Report of the Watson Trustees, as printed in *Science, n. s.*, Vol. I, No. 18.]

On the recommendation of the Board of Trustees of the Watson Fund, the Academy last year unanimously awarded the Watson medal to Seth C. Chandler, of Cambridge, Mass., for his investigations relative to variable stars, his discovery of the period of variation of terrestrial latitudes, and his researches on the laws of that variation. It is the pleasant duty of the Trustees to set forth the grounds on which this award was recommended.

It is a result of the well-known laws of dynamics relating to the rotation of a rigid body, as the Earth is assumed to be, upon its axis, that the poles of the Earth may be determined in two ways. Our globe, being a spheroid flattened at the poles and protuberant at the equator, has a certain axis passing between the points of greatest flattening. This axis has no direct connection with the rotation of the Earth; it would exist if the latter, retaining its present form, did not rotate at all. It is called the axis of figure, being determined altogether by the shape of the Earth.

But the Earth has also an axis around which it rotates. Now, assuming the Earth to be a rigid solid, there is no necessity that the axis of rotation should correspond to that of the axis of figure just described. We could take a solid body, pass an axis through it in any direction, and make it rotate on that axis.

It was shown by Euler, more than a century ago, that if a solid body rotated on an axis different from that of figure, the position of the axis of rotation in the body would be subject to a slow change, consisting in a constant revolution around the axis of figure. Were this body the Earth, the latitude of a place, as determined by astronomical observation, would change in the same way. The time of one revolution of the pole would depend upon the figure of the Earth. The flattening of the Earth is such that, were it a perfectly rigid body, the time of revolution would be about 305 days; that is to say, the north pole would make its circuit in a period of 305 days.

There being no necessity that the two poles should coincide, the question was naturally raised whether, perhaps, there might actually be such a difference of the two poles, and, in consequence, a change of latitude of every place on the Earth's surface having a period of 305 days. The first to investigate this question with all the refinements of modern astronomy was C. A. F. PETERS, who, half a century ago, was an assistant at the Pulkowa Observatory. In his classic paper on the parallax of the fixed stars, one section is devoted to the question of the variability of the latitude in a period of 304 days, which, according to the then accepted value of the flattening of the Earth, would be the time of one revolution of the poles. He found a coefficient of 0″.079, with a probable error of 0″.017. This result was so extremely minute that it might have arisen from unavoidable sources of error; and the conclusion therefore reached was that if there was any such separation of the two poles, it was too small to be certainly detected by the most refined observations.

In 1862, our late fellow-member, Professor HUBBARD, of the Naval Observatory, commenced a series of observations with the prime-vertical transit of that institution, which would be available for the same research. They were interrupted after a little more than a year, by his untimely death, but were continued four years longer by his successors. The result was the same as that reached by PETERS; no change having a period of 305 days could be detected.

In 1873 the question was investigated by NYRÉN in connection with a longer series of observations on the latitude of the Pulkowa Observatory. His results were somewhat discordant, and the only conclusion that could be drawn from them was that the variation could not be certainly detected by these most refined observations.

Ten years later, NYRÉN repeated the determination, in connection with his observations for the determination of the constant of aberration. These observations, made with the prime-vertical transit, were carried through with the minutest attention, and the utmost care to avoid every conceivable source of error. Curious discordances were nevertheless found in the results for the constant of aberration.

In 1885, **Küstner** showed that they could be accounted for by supposing a change going on in the latitude. But nothing could be inferred respecting the law or the cause of the change.

As a result of these investigations, the coincidence of the earth's axes of rotation and of figure has, until within a very few years, been assumed by astronomers as a practically established fact; and all their methods of observation have rested upon the idea of absolute coincidence. This confidence has not been disturbed until within a few years, when the question has been reopened. But it has now apparently been settled upon a new and firmly established basis.

Dr. **Chandler's** work upon this subject began with observations made by him in 1884–85, using a novel form of astronomical instrument, of his own invention. These observations, continued uninterruptedly for thirteen months, revealed a progressive change of a pronounced periodical character in the instrumental values of the latitude. In publishing these results, in 1885, he announced his intention to continue the research throughout the remainder of that year. Yet circumstances prevented him from carrying out his intention at that time, and he did not resume his examination of the subject until six years later. Meanwhile, Dr. **Küstner**, at the Observatory of Berlin, in 1888, published a memoir on the Constant of Aberration, as deduced by him from a series of observations, also made in 1884–85, simultaneously with **Chandler's** series, which brought to light anomalies of an entirely analogous character. **Küstner's** series was not continuous enough to show the periodic nature of the phenomenon; but, by an exhaustive examination of the possible subjective sources of error, he clearly demonstrated that it was no longer permissible to retain the hypothesis of an invariable position of the pole, and he recommended that properly organized observations, at various places, be instituted to settle the question definitely. It was doubtless this work of **Küstner's** which compelled the attention of astronomers to the subject. As a result, by the coöperation of three German observatories, under the auspices of the International Geodetic Association, and the independent action of that at Pulkowa, the fact of the variability of terrestrial latitude was placed beyond question, and, by a corresponding series, made at the Sandwich Islands, the further fact was established that the variable element is the position of the axis of rotation with respect to the earth's body, and not its position in space.

It was just before this point that a renewal of CHANDLER'S connection with the problem began. The results are published in a series of eighteen papers in the *Astronomical Journal* (1891–94), exclusive of a series of five papers upon a topic closely related thereto, and involving it; namely, the aberration-constant, which will be separately spoken of later.

The keynote of these investigations, and the undoubted cause of the success which has attended them, lies in the fact that at the outset he first recognized the necessity of deliberately disregarding all teachings of the adopted theory, which had misled previous investigators, and of examining the facts by a purely inductive process, taking nothing for granted, and basing all conclusions strictly upon the observations themselves.

It is impossible to give here more than a bare statement of the principal results thus established, which we arrange in their natural order, and not in the historical order of their derivation.

1. The phenomenon is not a local or a regional, but a terrestrial, one; also it is a displacement of the Earth's axial rotation with reference to the principal axis of inertia, and not of the direction of the former in space.

2. The axis of rotation, although fixed as regards its direction in space, performs a relative revolution about that of inertia in a period of 428 days. This motion is circular, with an average radius of about fourteen feet, and its direction is from west to east.

3. Simultaneously with the above motion, the actual position of the principal axis of inertia on the Earth's surface is in motion about a mean position, in a period of a year. Its direction is also from west to east, but is in an ellipse, three or four times as long as broad, the major and minor axes being about twenty-five feet and eight feet respectively. The major axis is inclined at present, by about 45° to the Greenwich meridian. The motion is central, obeying the law of proportionality of times to areas described by the radius vector about the center of the ellipse.

4. Both the radius and period in the circular 428 days' revolution are systematically variable; the former being about eight feet and eighteen feet, the latter between about 423 and 434 days; in a long period of apparently about sixty-six years. In this ine-

quality of motion the average angular velocity is attained when the size of the circle is least, or greatest when the circle has its mean dimensions.

5. Similarly there are simultaneous changes in the apparent dimensions and velocity in the annual period, which are complementary in their character to those in the 428 days' revolution; but whether they are the result of real changes in the form and dimensions of the ellipse or the effect of an apsidal motion of long period, cannot at present be determined from the observations available. All that can be said is that observations during five years show that the line of apsides is either fixed, or, if variable, revolving at a very slow rate.

6. Besides these two motions of relatively short period, there is distinct evidence of a third motion of rotation in a much larger term, probably not far from twelve years, with a radius of ten or fifteen feet, which reconciles similar indications of slow changes which had been pointed out by other investigators. (*A. J.*, XII, 178; XIII, 35, 36.)

The results thus established are the outcome of the examination of an immense number of observations, covering the whole interval since the era of refined practical astronomy began, and in fact practically exhaust the materials which may be drawn for this purpose from existing astronomical annals. The endeavor to make the discussion exhaustive in this respect made it necessary to completely reduce, from the original instrumental readings, extensive older series of observations. It has, incidentally, for example, rescued from almost complete oblivion the series of POND, 1825–36, and has shown that work to be of a character which will compare favorably with the most refined observations made with the meridian instruments of the present day.

Intimately connected with the work on the variation of latitude are five additional papers, containing a redetermination of the value of the aberration-constant from eight different series of observations at the Pulkowa Observatory, with the prime-vertical transit and the vertical circle. The correct value of this fundamental element is one of the most important questions occupying the astronomy of the day.

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NOTICES FROM THE LICK OBSERVATORY.

PREPARED BY MEMBERS OF THE STAFF.

THE CROSSLEY REFLECTOR.

At the dinner of the Alumni Association of the University of California, given in San Francisco on April 30, 1895, in honor of the Governor of the State and of members of the State Legislature, the following letter was read:

THE LICK OBSERVATORY,
MT. HAMILTON, April 25, 1895.

To the Secretary of the Alumni Association of the University of California:

My Dear Sir—I beg to thank you for an invitation to attend the banquet of the Alumni Association of the University of California, at which Governor BUDD and members of the Legislature will be your honored guests.

I should certainly accept your invitation, and do my part in thanking those who have rendered such signal services to the University, if I were not detained here by a very important work now going on, which I ought not to leave for the three days necessary for a journey from Mount Hamilton to San Francisco and return.

The work I refer to consists in preparing a site on Mount Hamilton to receive the great reflecting telescope lately presented to the University by Mr. EDWARD CROSSLEY, F. R. A. S., of Halifax, Yorkshire, England. As every graduate of the University has a personal interest in this magnificent present, I beg you to allow me a few moments to give certain particulars relating to it.

The original plans on which the LICK Observatory is now built were made by Professor NEWCOMB and myself in 1874, more than twenty years ago. Mr. LICK had provided that his observatory should possess the most powerful telescope in the world, and the 36-inch refractor, now mounted here, fulfilled this condition. It was proposed to supplement the great refractor by a large reflector. During the years 1874 to 1887, the plan of erecting a large reflector here was constantly kept in mind. It was finally abandoned, because the available funds did not warrant the necessary expense.

Since the Observatory has been part of the University—since June 1, 1888,—the need for such a telescope has been felt, especially during the past two or three years. There are certain spectroscopic and photographic researches in which the reflector has a distinct advantage over the refractor; just as the latter is superior to the former in certain other fields. The two instruments are not rivals, but coadjutors. Each has its province. One is emperor; the other, pope.

Not only was the general question of procuring a reflector kept in view, but particular steps were made in this effort. A certain 3-foot reflector, now happily the property of the University, was made by Mr. A. A. COMMON, F. R. S., in 1879, and used by him with great success. It was subsequently purchased from Mr. COMMON by Mr. EDWARD CROSSLEY, then Member of Parliament for Halifax, himself an enthusiastic amateur of astronomy. Learning that Mr CROSSLEY was preparing to dispose of this reflector, I endeavored, some two years ago, to procure the money necessary to buy it for the LICK Observatory. Owing to the depression in business here, it was not then practicable to raise the requisite funds. Mr. CROSSLEY'S attention was thus fixed upon the great astronomical advantages of the site at Mount Hamilton, and he at once saw that a telescope placed here would be able to render services to science far greater than those which could be expected in a climate like that of England. The LICK Observatory was also an established part of a great University belonging to a rich State; and it had already shown by its work the mettle of the competent and faithful observers who form its staff. Mr. CROSSLEY was impressed by all the advantages named, and when it was finally proposed to him to give us his great telescope, with its apparatus and dome, outright, he most generously and liberally agreed to do so. Early in April his telegram offering this gift to the LICK Astronomical Department of the University was received. His letter making the formal proposal is dated April 6th.

In order to accept this gift, it was necessary to raise a sum of money to pay the cost of dismounting the telescope and dome in England, of transporting them to California, and of setting them in place ready for work at Mount Hamilton. The University being short of ready money, it seemed desirable to propose to certain representative citizens of California to subscribe to the desired fund. Accordingly, during the past week the funds necessary to the acceptance of the telescope have been obtained; and, at the meeting of the Regents on April 30th, the generous gift of Mr. CROSSLEY will be definitely accepted. One word as to the contributors to the fund for installing the CROSSLEY Reflector. Every gift to the fund was made not only cheerfully, but with positive pleasure—all were glad to give towards an object so useful and so honorable to the State and to science. Every class of our citizens is represented. We have contributions from Regents of the University, from professors, from the Alumni, from the Astronomical Society of the Pacific, from the Society of California Pioneers, and the California Academy of Sciences, from bankers, manufacturers, railway officials, lawyers, men of business, capitalists—both men and women.

The gift of Mr. CROSSLEY is, in the first place, a gift from an individual to the State of California. It has been accepted by representative citizens, and it will be turned over to the care of the Regents for the use of the University. It should be a source of gratification to Californians that Mr. CROSSLEY has chosen to make his gift to a Californian institution. There are many important observatories in England, in India, in the Colonies of Africa and Australia, any one of which would have been delighted to receive Mr. CROSSLEY'S magnificent present, and any one of which would have made excellent use of it. Mr. CROSSLEY has chosen out of them all that observatory in which he considered his telescope would be most useful. I wish to point out to you that this gift is a striking evidence that true science is universal, and that the spirit which prompted Mr. CROSSLEY to place his telescope where it can be used to the best advantage, is high-minded and truly scientific in a marked degree.

The work of preparing the site for the new telescope and dome has already begun. In a few weeks the telescope will be on its way from England. In a few months it will be set up at Mount Hamilton. If all goes well, I hope to see valuable observations made with it during the present season. Promptness in putting Mr. CROSSLEY'S gift to use will show how deeply we appreciate his kindness and generosity. The University of Chicago is now setting up its great telescope, which is somewhat larger than the LICK Refractor; but the addition of the CROSSLEY Reflector to our instruments will still keep the LICK Observatory in its position as the most powerfully equipped observatory in the world.

When you are thanking the Governor of California, and the Senators and Representatives of the State, for their care of the best interests of the University — thanks in which I beg to join — do not forget our English friend beyond the seas who has put into our hands a most powerful instrument of research — an instrument which already has an honorable history, to which the astronomers of the LICK Observatory hope to add new and important chapters.

I am, my dear sir,

Very respectfully and truly yours,

EDWARD S. HOLDEN.

ACCEPTANCE OF THE CROSSLEY REFLECTOR AND DOME BY THE REGENTS OF THE UNIVERSITY OF CALIFORNIA.

At meetings of the Regents of the University held in April, May and June, the following resolutions were adopted:

Whereas, Mr. EDWARD CROSSLEY, F. R. A. S., of Halifax, Yorkshire, England, has offered in his letter of April 6, 1895, to present to the LICK Astronomical Department of the University of California his 3-foot reflecting telescope, with its apparatus and its dome, complete;

Resolved, That the Regents of the University of California gratefully accept this splendid addition to the resources of the LICK Observatory, which makes it the best-equipped observatory of the world;

Resolved, That the Regents recognize in this gift a striking evidence that true science is universal, and that they cordially appreciate the high-minded and scientific spirit which prompted Mr. CROSSLEY to place his powerful telescope on the site where it can be used to the best advantage of astronomy;

Resolved, That the telescope, when installed at Mount Hamilton, shall be known and designated as the *CROSSLEY Reflector;*

Resolved, That the Secretary of the University transmit a certified copy of these resolutions to Mr. CROSSLEY.

Whereas, The following named friends of the LICK Astronomical Department of the University of California have generously contributed to the fund for installing the CROSSLEY Reflector at Mount Hamilton, namely: WILLIAM ALVORD; T. ELLARD BEANS, Miss C. B. BRUCE, JAMES V. COLEMAN, GEORGE CROCKER, HENRY J. CROCKER, J. B. CROCKETT, CHRISTIAN DE GUIGNÉ, Mrs. PETER DONAHUE, J. A. DONOHOE, CHARLES GOODALL, ROBERT Y. HAYNE, ALVINZA HAYWARD, I. W. HELLMAN, EDWARD S. HOLDEN, EDWARD W. HOPKINS, JAMES F. HOUGHTON, C. P. HUNTINGTON, GEORGE R. LUKENS, CHARLES MAYNE, ALBERT MILLER, D. O. MILLS, W. S. MOSES, CHARLES NELSON, A. H. PAYSON, PERCY and HAMILTON, Mrs. JOHN PARROTT, Sr.; JOHN PARROTT, Jr., JAS. D. PHELAN, WM. M. PIERSON, JAMES B. RANDOL, LOUIS SLOSS, Southern Pacific Company, LEVI STRAUSS, ALEX. BLAIR THAW, Union Iron Works, United States Express Company, WELLS, FARGO & CO.;

Resolved, That the Regents of the University gratefully accept these gifts, which will be applied to the purpose named;

Resolved, That the Secretary of the University be instructed to transmit a copy of these resolutions to each contributor.

METEOR OF MARCH 2, 1895.

CARSON CITY, NEV., May 9, 1895.

My Dear Professor Holden:

In the last *Publications* of the Astronomical Society of the Pacific, I see a notice of a meteor observed on March 2, 1895, at Virginia and Reno, Nev., and as the data therein do not quite correspond with those that I have, I will give you the observation and measurements of Col. E. D. BOYLE, a member of the Society. Course of meteor, NW. to SE.; altitude above horizon, about 60°; point of explosion, 35° above horizon, and 65° east from south; time elapsed between explosion and sound, $1^m\ 25^s$; time of explosion, 5:45 A. M., Pacific standard time, observed at Gold Hill, Storey Co., Nevada.

Yours sincerely, C. W. FRIEND.

DATA RELATING TO THE SITE OF THE CROSSLEY REFLECTOR.

The site for the CROSSLEY Reflector is to be on the summit called *Mount Ptolemy* (see Hand-book of the LICK Observatory, p. 18), about 1000 feet south of the Great Dome, and near the brick cottages built for Professors BARNARD and CAMPBELL in 1894.

A road winds up the west side of *Mount Ptolemy*, past the two cottages, and directly round the south wall of the CROSSLEY Dome, and returns to the point of starting, along the eastern slope of the hill. This road was entirely completed May 16, 1895.

The rain water from the cottages and dome (about 80,000 gallons per year) will be collected in tanks at a point near where these roads join the regular stage-road from San José (about 177.6 feet below the marble floor of the L. O.), and from thence pumped by a windmill to a new reservoir, to be built some 100 feet south of the Great Dome, and about 25 feet lower than the L. O. floor. Surplus water from this reservoir will flow into *Huyghens Reservoir*, whose top is 31 feet below the marble floor. On the other hand, the new reservoir can be filled from *Kepler Reservoir* (46 feet above L. O.) or from *Copernicus Reservoir* (174 feet above L. O.). This rain-water will be used for power at the CROSSLEY Dome, whose floor will be about 120 feet lower, and for fire protection at the new cottages. The first floor of Professor CAMPBELL'S cottage (the cottage which is highest and furthest south) is about 147 feet lower than the L. O.

The data for the above-named elevations are derived from a survey by Professor CAMPBELL. E. S. H.

A METEOR SEEN AT SEA, MARCH 29, 1895.

The report that the steamship Nessmore, at this port, from London, had been struck by a meteor, briefly noted in the papers the day following her arrival, has attracted wide attention from those interested in ocean phenomena. Capt. RICHARDSON has given a very careful description of the incident, with the atmospheric conditions prevailing at the time.

March 29th the steamship was off the southern end of the Newfoundland banks. The day opened perfectly, and at noon a good observation was had. At 12:30 o'clock the weather changed; a dense and black fog suddenly set in, completely enveloping the steamer. At this moment, without any warning whatever, a terrific explosion was heard, coming from the direction of the foremost top pole head. A vivid flash of a whitish color accompanied the explosion, and small particles of what appeared to be white ash matter were seen to fall to the deck.

Of course, all hands were greatly startled, and Capt. RICHARDSON, who was on the bridge, stopped the steamship. Explaining his astonishment, he said that he at first thought that some man-of-war had fired a shell at him. Recovering his composure, and finding the vessel all right, she was started ahead again. An examination of the fore pole showed a splinter of wood projecting from it at right angles, and a sailor was sent aloft to investigate. He found the pole split across and downward for three feet. The paint was burned off the entire length of the pole.

Directly after the explosion a very heavy rain set in, lasting about twenty minutes. Then the rain ceased, the fog lifted, and the sun came out brilliantly for about thirty minutes, when the fog again surrounded the vessel. The meteor, or whatever it was, came from an easterly direction. At the time, the wind was light from the south. There was no lightning either before or after the explosion.—*The Boston Herald.*

A BRIGHT METEOR.

At $4^h\ 31^m$ on the morning of April 2, 1895, an unusually bright meteor swept from the direction of δ *Aquilae*, bursting and disappearing just north of β *Aquarii.* Its brightness was about equal to the seven-days-old Moon. Its color was white. It was visible only one or two seconds, and left but faint indications of a train, which disappeared rapidly. There was no noise.

C. D. P.

STUDENTS AT THE LICK OBSERVATORY, 1895.

The following students will work at Mount Hamilton during the summer of 1895:

Professor ROBERT G. AITKEN, M. A. (Williams College), now Professor of Mathematics and Astronomy in the University of the Pacific . . . . *Special.*

Mr. WILLIAM H. WRIGHT, B. S. (University of California, 1893). . . . . *Candidate for* M. S.

BIOGRAPHICAL SKETCH OF CHARLES W. TUTTLE (1829–1881), FORMERLY ASSISTANT IN HARVARD COLLEGE OBSERVATORY.

The *New England Historical and Genealogical Register*, Vol. 42, page 1, contains an extended sketch of the life of CHARLES W. TUTTLE, Assistant in Harvard College Observatory (1850–1854), with an excellent portrait on steel. Mr. TUTTLE is known to astronomers by his observations of the dusky ring of *Saturn* (1850), his discovery of a comet (1853), and other work of importance. E. S. H.

CUT OF THE LUNAR APENNINES.

The cut of the lunar Apennines in the present number is reproduced from a heliogravure in Volume III of the *Publications* of the LICK Observatory. We owe this cut to the courtesy of the editor of *McClure's Magazine*. E. S. H.

COMPARISON STARS OBSERVED WITH THE MERIDIAN CIRCLE.

The two stars used for the determination of *Eucharis*, at this opposition, have been observed with the Meridian Circle.

The numbers, in accordance with the system in use heretofore, represent the hours, minutes, and seconds of the A. R., for the epoch 1900.

No.	Mag.	A. R.		1895.0.	Decl.		
		h.	m.	s.	°	′	″
125733	*9¾	12	57	18.52	+ 16	6	42.9
130138	9½	13	1	23.70	+ 15	35	24.4

* N. fol. of close pair.

Two observations have been given to each star.

R. H. TUCKER.

A LARGE METEOR.

TRACY, April 17, 1895.—A large meteor was seen this evening at 6:53 o'clock, to the southeast, at an altitude of about 40°, moving westward. When near the horizon to the southwest, it exploded, breaking into three bright fragments.—*S. F. Chronicle*, April 18, 1895.

COMPLETION OF THE BRICKWORK OF THE CROSSLEY DOME.

It is expected that all the brickwork for the new CROSSLEY dome, including an entrance portico, a photographic dark-room, a bedroom for a janitor, a study for an astronomer, and a winch-room, will be entirely completed about July 10th. The walls of the dome will be surmounted by a cap of artificial stone, to receive the iron rail on which the dome is to turn. The telescope left England on June 28th. E. S. H.

LEVELS.—DISTANCES BELOW MARBLE FLOOR OF THE LICK OBSERVATORY. (4209 FEET ABOVE SEA.)

	Feet.
I.—At bend in stage-road south of 36″ Dome (nail driven in base course of brick at foot of slope going up to Dome)	26.32
II.—Plank walk north of N. W. corner of old east frame cottage	72.73
III.—Road opposite telephone pole No. 3	115.4
IV.—Top of landing for brick cottages	177.63
V.—Surface of road in saddle between L. O. and brick houses, about	180.
VI.—First floor south brick cottage	147.1
VII.—Floor of CROSSLEY Dome (about)	143.

W. W. CAMPBELL.

DEATH OF PROFESSOR DANIEL KIRKWOOD.

Professor DANIEL KIRKWOOD, the Dean of American Astronomers, and an honored member of this Society, died at his home in Riverside, California, on June 11, 1895. A history of his life and works has recently been printed, with a portrait.

He is best known to astronomers by his researches on the Asteroids, which have a permanent value in science. His personal friends will long remember his kindly, upright, and beautiful character and influence. No one could be with him without knowing that here was a true and a good man. E. S. H.

STUDENT AT THE LICK OBSERVATORY.

Mr. J. M. BROSIUS (B. S., Monmouth), Instructor in Mathematics and Astronomy in Napa College. . . . . . *Special.*

MERIDIAN CIRCLE OBSERVATIONS, 1894–1895.

Work with the meridian circle has been prosecuted as in th preceding year, the instrument having been used in the revers position — circle west.

There remain four hours of Right Ascension to be observe to complete the list in this position; and the extra stars, introduced in part from the Nautical Almanac for 1897, will the require one more set of observations.

Since beginning the series, 4000 observations have been made one half of which are completely reduced. For the remainder the reduction is one-third part done, bringing the results of computation in general to within six months of current observing.

R. H. T.

THE EMERSON McMILLIN OBSERVATORY OF THE OHIO STATE UNIVERSITY.

A letter from Professor H. C. LORD, of the Ohio State University, notifies that Mr. EMERSON McMILLIN has determined to found an observatory in connection with the State University of Ohio, of which Professor LORD is to be Director. The building is to be erected at the cost of Mr. McMILLIN, who has also given $10,000 for the purchase of a transit, a 12-inch equatorial, a spectroscope, etc. Work on the new establishment is to be commenced at once.

E. S. H.

THE ASTRONOMICAL SOCIETY OF BELGIUM.

A new astronomical society has lately been formed in Belgium, with its seat in Brussels. The object of the society is to advance science; but also to diffuse knowledge. The list of founders contains many well-known names. The congratulations of their colleagues in America are extended to the new organization, with best wishes for its usefulness and success.

Minutes of the Meeting of the Board of Directors, held at the Lick Observatory, June 8, 1895.

President Burckhalter took the chair, and a quorum was present. The minutes of the last meeting were approved. The following members were duly elected:

List of Members Elected June 8, 1895.

Charles L. Ackerman	426 California St., S. F.
Mr. Edward Crossley, F. R. A. S.,*	Bermerside Observatory, Halifax, England.
Mr. Willard B. Farwell	Room 9, 819 Market St., San Francisco, Cal.
Mr. H. M. Gorham	Gold Hill, Nevada.
University of Chicago Library	Dept. of Astronomy, Chicago, Ill.
Professor Henry C. Lord	Director of the McMillin Observatory, Ohio State University, Columbus, Ohio.
Mr. W. F. Main	College and Dubuque Sts., Iowa City, Iowa.
Mr. Enos Putman*	Grand Rapids, Michigan.
Mrs. Enos Putman	Grand Rapids, Michigan.
Miss Estelle R. Putman	Grand Rapids, Michigan.
Miss Helen R. Putman	Grand Rapids, Michigan.
Mr. Jacob H. Schiff*	932 Fifth Ave., New York, N. Y.
Baron A. v. Schweiger-Lerchenfeld	Kleine Neugasse 13, Vienna, Austria.
Dr. G. E. Shuey	651 E. Fourteenth St., East Oakland, Cal.
Mr. Robert Stevenson	P. O. Box 2214, San Francisco, Cal.
Mr. H. F. Stivers	Hunters, Tehama Co., Cal.
Mr. Charles Tousey Taylor	Kamela, Oregon.
Mrs. Louis Taussig	2127 California St., S. F., Cal.
Mr. Edward H. Van Ingen	9 East 71st St., New York, N.Y.
Rev. Henry Wood	St. Ignatius College, S. F., Cal.
Mr. William H. Wright	Lick Observatory, Mt. Hamilton, Cal.

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* A star signifies life membership.

The following was adopted:

In recognition of the generous gift by Mr. EDWARD CROSSLEY, F. R. A. S., of his 3-foot reflector and its dome to the LICK Observatory,

Resolved, That Mr. CROSSLEY be elected a life member of the Astronomical Society of the Pacific, without payment of dues.

The following report from the Library Committee was accepted and adopted, and laid upon the table:

To the Board of Directors, Astronomical Society of the Pacific:

GENTLEMEN—The Library Committee presents the following report of the condition of the library:

A number of books have been out for some months, although requests have been mailed to the members to return them.

A number of books stand charged to the members taking them, although it is known that they have been returned, but not checked off.

The present arrangement of issuing books is unsatisfactory, in that it depends entirely upon the members remembering to leave a memorandum of the book they take out. Any member can take any book, the only condition being that he shall leave a memorandum noting same. This book is then charged against him, and credited to him on its return, if accompanied by a corresponding memorandum. If, however, another member sees this book upon the table between the time of its return and its being replaced on the shelves, he may take it out, and in the absence of a memorandum left by him it would still stand charged against the member taking it originally.

Many of the books are out for long periods of time, and usually they are those most needed for consultation.

Your committee respectfully suggests the propriety of setting aside certain books of reference for reference only, and not issue them to any of the members; also, that steps be taken to so regulate the issue and return of our books as to protect the best interests of the Society. Respectfully submitted.

E. J. MOLERA,
ROSE O'HALLORAN,
A. H. BABCOCK,
Library Committee.

1895, June 4.

On motion, it was

Resolved, That the Library Committee be requested to report whether an arrangement cannot be made with some one of the public libraries of San Francisco to care for the A. S. P. books and to issue them to our members without cost to the A. S. P., in return for the privilege of allowing their subcribers to consult A. S. P. books in their reading-rooms.

Resolved, That the Library Committee be requested to furnish the Secretaries with a list of those Corresponding Institutions whose names are printed on page 14 of Volume 7 of our *Publications*, which have sent none of their volumes in exchange for our own.

It was further, on motion,

Resolved, That the President appoint two members of the A. S. P. to act with himself as a Special Committee to determine whether it may not be desirable to change the rooms of the A. S. P. in San Francisco to another building.

It was, on motion,

Resolved, That in the death of Mr. JOSEPH A. DONOHOE, the generous founder of the comet medal of the Astronomical Society of the Pacific, and a life member of this Society, our organization has lost a cherished associate, and a sincere patron of astronomical science.

MINUTES OF THE MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD AT THE LICK OBSERVATORY, JUNE 8, 1895.

President BURCKHALTER presided. The minutes of the last meeting, as printed in the *Publications*, were approved.

The Secretary read the names of members duly elected at the meeting of the Directors.

The following papers were presented:

1. The Kodiakanal Solar Physics Observatory in India, by the Director, C. MICHIE-SMITH, F. R. A. S.
2. The CROSSLEY Reflector of the LICK Observatory, by Dr. EDWARD S. HOLDEN.
3. The Moon as seen by a Geologist—Abstract of a paper on the Moon by Professor SUESS, of Vienna, translated by Mr. C. A. STETEFELDT.
4. Planet-Notes for July and August, by Professor MALCOLM MCNEILL.
5. Recent Spectroscopic Observations of *Saturn* with respect to the determination of velocities of various portions of the System, by Professor W. W. CAMPBELL.
6. Description of a new 18-inch CASSEGRAIN Reflector, equatorially mounted, having an equivalent focal length of 250 feet, by Professor J. M. SCHAEBERLE.
7. On a Method of Photographing the Corona during a total eclipse, by which any part may be given any exposure desired on the same photographic plate, by Mr. CHARLES BURCKHALTER.

Adjourned.

OFFICERS OF THE SOCIETY.

CHAS. BURCKHALTER (CHABOT Observatory, Oakland), ... *President*
W. J. HUSSEY (LELAND STANFORD Jr. University, Palo Alto, Cal.), } . *Vice-Presidents*
E. S. HOLDEN (LICK Observatory)
O. VON GELDERN (819 Market Street, S. F.),
C. D. PERRINE (LICK Observatory), ... *Secretary*
F. R. ZIEL (410 California Street, S. F.), ... *Secretary and Treasurer*

Board of Directors—Messrs. BURCKHALTER, HOLDEN, HUSSEY, MOLERA, Miss O'HALLORAN, Messrs. PERRINE, PIERSON, SCHAEBERLE, STRINGHAM, VON GELDERN, ZIEL.

Finance Committee—Messrs. VON GELDERN, PIERSON, STRINGHAM.

Committee on Publication—Messrs. HOLDEN, CAMPBELL, BABCOCK.

Library Committee—Mr. MOLERA, Miss O'HALLORAN, Mr. BABCOCK.

Committee on the Comet-Medal—Messrs. HOLDEN *(ex-officio)*, SCHAEBERLE, HUSSEY.

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PUBLICATIONS ISSUED BI-MONTHLY.

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PUBLICATIONS

OF THE

Astronomical Society of the Pacific.

VOL. VII. SAN FRANCISCO, CALIFORNIA, AUGUST 1, 1895. NO. 43.

ON THE CALCULATION OF THE TRUE ANOMALY AND RADIUS VECTOR IN TERMS OF THE TIME IN AN ELLIPTIC ORBIT OF ANY ECCENTRICITY.

BY W. STEADMAN ALDIS.*

[Abstract.]

If m, u, v, be the mean, the eccentric, and the true anomalies, respectively, and r the radius-vector, of a body moving in an elliptic orbit, whose major axis is $2a$, and eccentricity e, the fundamental relations between these quantities are

$$m = u - e \sin u. \quad \quad (1)$$

$$\tan \frac{v}{2} = \sqrt{\frac{1+e}{1-e}} . \tan \frac{u}{2} \quad \quad (2)$$

$$r = a\,(1 - e \cos u) \quad \quad (3)$$

From these three equations, any three of the four quantities r, u, v, m, are theoretically determinable in terms of the fourth. The most important case is that of finding r, v, u, when m is given. The following is offered as a complete and easy practical solution of this problem in all cases:

Writing $\sin \phi$ for e, equation (1) becomes

$$m = u - \sin \phi \,.\, \sin u,$$

or

$$\begin{aligned} 2m &= 2u - 2 \sin \phi \,.\, \sin u \\ &= 2u - \cos(\phi - u) + \cos(\phi + u) \\ &= \{\phi + u + \cos(\phi + u)\} - \{\phi - u + \cos(\phi - u)\}. \end{aligned}$$

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* Howick, New Zealand.

If the function $\overline{\cos\theta + \theta}$ be denoted by C (θ) this equation can be written

$$2m = \mathrm{C}\,(\phi + u) - \mathrm{C}\,(\phi - u) \quad . \; . \; . \; . \quad (4)$$

If a table be formed giving the values of C (θ) for all values of θ, at small intervals, within such limits as to cover all required values of $\phi - u$ and $\phi + u$, the value of m is known when that of u is given. It is only requisite to take the two values of C (θ) corresponding to $\theta = \phi + u$ and $\theta = \phi - u$, from the table, subtract the latter from the former, and halve the difference. The determination of u when m is given is effected by finding two consecutive values of u such that, for one of them, the value of $\mathrm{C}\,(\phi + u) - \mathrm{C}\,(\phi - u)$ falls short of, and for the other, exceeds, $2m$. The method of proportional parts will then give the sought value of u with all requisite exactness.

NOTE.—The paper of which the foregoing is a brief abstract was accompanied by a specimen of the proposed table, in which the argument is given (for every minute of arc) from 28° 0′ to 31° 0′; and in which the function is given in seconds of arc and tenths of a second, with a difference column.

PLANETARY PHENOMENA FOR SEPTEMBER AND OCTOBER, 1895.

BY PROFESSOR MALCOLM MCNEILL.

SEPTEMBER.

The autumnal equinox occurs, and the Sun crosses the equator from the north to the south, on September 22d, at about 11 P.M., Pacific time.

Eclipses. There will be two during the month.

(1.) *An Eclipse of the Moon* on the evening of September 3d. It will be total, and the entire eclipse will be visible throughout the United States. The times of the phases are as follows (P. S. T.):

			H.	M.	
Moon enters penumbra,	Sept.	3,	6	48	P.M.
Moon enters shadow,	"	3,	8	0	
Total eclipse begins,	"	3,	9	6	
Middle of the eclipse,	"	3,	9	57	
Total eclipse ends,	"	3,	10	47	
Moon leaves shadow,	"	3,	11	54	
Moon leaves penumbra,	"	4,	1	6	A.M.

(2.) *A Partial Eclipse of the Sun* on September 18th. It will be visible only over a portion of the southern hemisphere. It may be seen wholly or in part in Eastern Australia, New Zealand, and the Fiji Islands.

Mercury is an evening star throughout the month, gradually moving out toward east elongation; but, on account of its great distance south of the sun, it will not be favorably situated for naked-eye observation. At the end of the month it sets about 50^m later than the Sun. On September 1st it passes 1′ south of *Mars*, but the conjunction occurs while both planets are below our horizon in the early morning.

Venus is an evening star, but too near the Sun to be easily seen at the beginning of the month. It is in conjunction with the Sun on September 16th, and becomes a morning star. At the end of the month it rises rather more than an hour before the Sun.

Mars is also an evening star, but too close to the Sun to be seen. On September 1st it sets less than half an hour later, and at the end of the month only 10^m later than the Sun.

Jupiter is a morning star, and is getting far enough away from the Sun to be a conspicuous object for early risers. At the end of the month it rises a little after midnight. It moves 6° eastward during the month, and is in the constellation *Cancer*, not far from the "Bee-hive" cluster.

Saturn is an evening star, but is getting nearer the Sun, and at the end of the month remains above the horizon only a little more than an hour after sunset. It moves eastward in the constellation *Virgo* about 3°, passing north of the fourth-magnitude star *Lambda Virginis*. The nearest approach is on September 18th, when the planet is not quite 2° north of the star.

Uranus is also in the southwestern sky in the evening. It is in the constellation *Libra*, and moves eastward and northward about 1½°. The nearest naked-eye star, *Iota Libræ*, fifth maguitude, is 1° east and 2½° south of the planet.

Neptune is in the constellation *Taurus*, and by the end of the month rises a little before midnight.

OCTOBER.

Mercury is an evening star until October 25th, when it passes inferior conjunction with the Sun, and becomes a morning star. It passes greatest east elongation on October 1st, when it is not quite 26° east of the Sun; but, on account of its great southern declination (it is 12° south of the Sun), the conditions for visibility in the northern hemisphere are rather poor. At this elongation it sets about 50^m later than the Sun.

Venus is now a morning star, rapidly increasing its distance from the Sun, and moving eastward and northward. On October 1st it rises more than an hour before sunrise, and on October 31st about three and one-half hours before. It moves from the constellation *Leo* into *Virgo*. Toward the close of the month it attains its maximum brightness, and will be brilliant enough to be seen in full daylight, without telescopic aid, if one only knows where to look for it.

Mars is apparently very near the Sun, setting just after sunset on October 1st, and rising a few minutes before sunrise on October 31st. It is in conjunction with the Sun on the morning of October 11th. It had passed its maximum distance from the Earth about three weeks earlier; at that time it was about 244,000,000 miles from the earth — more than six times its distance at the opposition of October, 1894,—and the light it gives us is only about one-fortieth as much.

Jupiter is getting into better position. By the end of the month it rises at about 11 P.M. During the month it moves about 4° eastward through the constellation *Cancer*. It moves from a position a little south of the "Bee-hive" cluster, passing 19′ south of the fifth-magnitude star *Delta Cancri* on October 19th.

Saturn has ceased to be a conspicuous object. On October 1st it sets about $1^h\ 20^m$ after the Sun, and at the end of the month only about a quarter of an hour later. It will not be possible to follow it with the naked eye more than a few days after the beginning of the month. When it comes into good position for early morning observation on the other side of the Sun, the rings will be perceptibly wider open than they have been during the last few months. It moves eastward about 3° in the constellation *Virgo*.

Uranus is also drawing nearer the Sun, setting less than two hours later on October 1st. On account of its small magnitude (about sixth), it will not be easy to see it much after the beginning of the month. During the month it moves more than 1° eastward in the constellation *Libra*.

Neptune is in the eastern part of the constellation *Taurus*, and is well above the horizon some time before midnight. As it is of the eighth magnitude, it requires a telescope to show it, and it cannot readily be found without the use of setting-circles on the telescope.

EXPLANATION OF THE TABLES.

The phases of the Moon are given in Pacific Standard time. In the tables for Sun and planets, the second and third columns give the Right Ascension and Declination for Greenwich noon. The fifth column gives the local mean time for transit over the Greenwich meridian. To find the local mean time of transit for any other meridian, the time given in the table must be corrected by adding or subtracting the change per day, multiplied by the fraction whose numerator is the longitude from Greenwich in hours, and whose denominator is 24. This correction is seldom much more than 1^m. To find the standard time for the phenomenon, correct the local mean time by *adding* the difference between standard and local time if the place is west of the standard meridian, and *subtracting* if east. The same rules apply to the fourth and sixth columns, which give the local mean times of rising and setting for the meridian of Greenwich. They are roughly computed for Lat. 40°, with the noon Declination and time of meridian transit, and are intended as only a rough guide. They may be in error by a minute or two for the given latitude, and for latitudes differing much from 40° they may be several minutes out.

PHASES OF THE MOON, P. S. T.

		H. M.
Full Moon,	Sept. 3,	9 55 P. M.
Last Quarter,	Sept. 11,	8 51 P. M.
New Moon,	Sept. 18,	12 55 P. M.
First Quarter,	Sept. 25,	10 23 A. M.

THE SUN.

1895.	R. A. H. M.	Declination. ° ′	Rises. H. M.	Transits. H. M.	Sets. H. M.
Sept. 1.	10 42	+8 17	5 29 A M.	12 0 M.	6 31 P.M.
11.	11 18	+4 34	5 39	11 57 A.M.	6 15
21.	11 54	+0 42	5 48	11 53	5 58
Oct. 1.	12 30	−3 12	5 58	11 50	5 42

MERCURY.

1895.	R. A. H. M.	Declination. ° ′	Rises. H. M.	Transits. H. M.	Sets. H. M.
Sept. 1.	11 31	+ 4 1	6 33 A.M.	12 50 P.M.	7 7 P.
11.	12 28	− 3 27	7 15	1 7	6 59
21.	13 18	− 10 6	7 51	1 18	6 45
Oct. 1.	14 2	− 15 22	8 12	1 22	6 32

VENUS.

Sept. 1.	12 2	− 8 5	7 44 A.M.	1 20 P.M.	6 56 P.
11.	11 48	− 7 58	6 50	0 27	6 4
21.	11 27	− 5 42	5 43	11 27 A.M.	5 11
Oct. 1.	11 11	− 2 27	4 36	10 31	4 26

MARS.

Sept. 1.	11 31	+ 4 4	6 33 A.M.	12 50 P.M.	7 7 P.
11.	11 55	+ 1 27	6 26	12 34	6 42
21.	12 19	− 1 12	6 19	12 18	6 17
Oct. 1.	12 43	− 3 51	6 13	12 3	5 53

JUPITER.

Sept. 1.	8 6	+ 20 33	2 8 A.M.	9 25 A.M.	4 42 P.
11.	8 14	+ 20 10	1 39	8 54	4 9
21.	8 22	+ 19 47	1 8	8 22	3 36
Oct. 1.	8 28	+ 19 26	12 37	7 49	3 1

SATURN.

Sept. 1.	14 7	− 10 28	9 58 A.M.	3 25 P.M.	8 52 P.
11.	14 11	− 10 48	9 23	2 49	8 15
21.	14 14	− 11 9	8 49	2 14	7 39
Oct. 1.	14 19	− 11 32	8 14	1 38	7 2

URANUS.

Sept. 1.	14 56	− 16 29	11 8 A.M.	4 14 P.M.	9 20 P.
11.	14 58	− 16 35	10 31	3 36	8 41
21.	15 0	− 16 43	9 54	2 59	8 4
Oct. 1.	15 2	− 16 51	9 17	2 21	7 25

Neptune.

1895.	R. A.	Declination.	Rises.	Transits.	Sets.
	H. M.	° ′	H. M.	H. M.	H. M.
Sept. 1.	5 8	+ 21 28	11 6 P.M.	6 27 A.M.	1 48 P.M.
11.	5 9	+ 21 28	10 27	5 48	1 9
21.	5 9	+ 21 28	9 48	5 9	12 30
Oct. 1.	5 9	+ 21 27	9 9	4 30	11 51 A.M.

Phases of the Moon, P. S. T.

		H. M.
Full Moon,	Oct. 3,	2 47 P. M.
Last Quarter,	Oct. 11,	6 34 A. M.
New Moon,	Oct. 17,	10 10 P. M.
First Quarter,	Oct. 25,	3 4 A. M.

The Sun.

1895.	R. A.	Declination.	Rises.	Transits.	Sets.
	H. M.	° ′	H. M.	H. M.	H. M.
Oct. 1.	12 30	− 3 12	5 58 A.M.	11 50 A.M.	5 42 P.M.
11.	13 6	− 7 2	6 8	11 47	5 26
21.	13 43	− 10 43	6 19	11 45	5 11
31.	14 22	− 14 8	6 30	11 44	4 58

Mercury.

Oct. 1.	14 2	− 15 22	8 12 A.M.	1 22 P.M.	6 32 P.M.
11.	14 29	− 18 14	8 10	1 9	6 8
21.	14 18	− 16 7	7 12	12 19	5 26
31.	13 39	− 9 19	5 31	11 2 A.M.	4 33

Venus.

Oct. 1.	11 11	− 2 27	4 36 A.M.	10 31 A.M.	4 26 P.M.
11.	11 8	+ 0 8	3 45	9 49	3 53
21.	11 19	+ 1 12	3 13	9 21	3 29
31.	11 41	+ 0 48	2 58	9 3	3 8

Mars.

Oct. 1.	12 43	− 3 51	6 13 A.M.	12 3 P.M.	5 53 P.M.
11.	13 7	− 6 28	6 5	11 47 A.M.	5 29
21.	13 32	− 9 2	6 0	11 33	5 6
31.	13 57	− 11 31	5 55	11 19	4 43

OFFICERS OF THE SOCIETY.

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AS DATIONS
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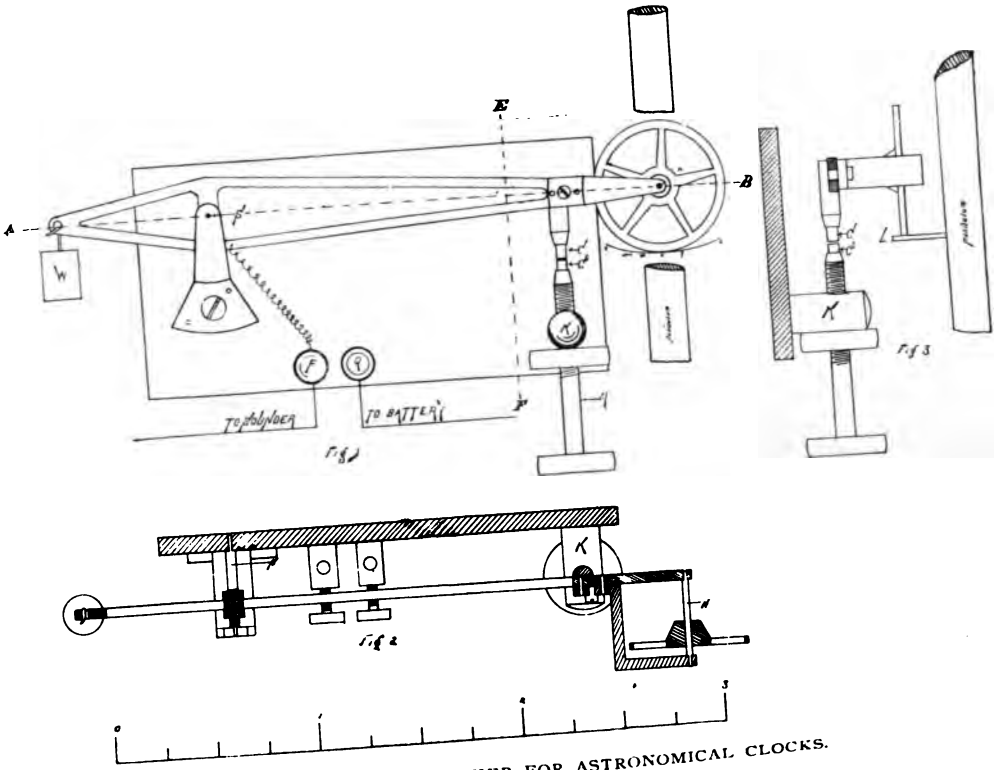
A NEW CIRCUIT-BREAKER FOR ASTRONOMICAL CLOCKS.

By A. F. Poole.

Various devices have been invented for sending regular electric signals from a clock, but none of them have given entire satisfaction when applied to clocks having the Graham dead-beat escapement. The trouble arises principally from the mode of operation of this escapement. In it the energy of the falling weight is given *directly* to the pendulum, there being no provision for correcting inequalities in the motive force, as is the case with a gravity escapement. One of the chief factors in a good clock rate is the absolute uniformity of the impulse given to the pendulum at each vibration. If this impulse varies, the clock rate will vary with it. Any circuit-breaker, applied to a dead-beat clock, must of necessity be worked either directly by the pendulum or by a part of the force which gives the impulse to the pendulum. In either case, if the work required to operate the breaker is variable, the effective impulse given to the pendulum will also be variable, and so also will be the clock rate. From this we have, at once, the conditions which must be fulfilled by a satisfactory circuit-breaker for a clock having a Graham escapement, viz.: the work done in breaking the circuit each time a signal is sent should be absolutely constant. It is also desirable, though not essential, that this work be as small as possible.

It was with the view of fulfilling the conditions of having the work both constant and small that I made the circuit-breaker described in this article. By means of a series of experiments made in the Physical Laboratory of the Leland Stanford Jr. University, I have investigated the work required to operate this instrument. Through the kindness of Professors Holden and Tucker, its efficiency, in actual use, has been tested on one of the Hohwu clocks of the Lick Observatory. Professor Tucker's account of its performance is given in an article immediately following. A description of the instrument and an account of the laboratory experiments are given in the following paragraphs.

An idea of the breaker can be obtained from the accompanying cut. Three views are given: Figure 1 is a plan, figure 2 a hor-



A NEW CIRCUIT-BREAKER FOR ASTRONOMICAL CLOCKS.

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izontal section through the center of the beam *AB*, figure 3 is a vertical section through *DE*. A scale of inches is given at the bottom of the cut.

The breaker consists of a light metallic beam, pivoted at *S*; at the end of the beam is a light wheel, which is free to turn about the staff *N*; at the other end is a counterpoise, *W*. A platinum contact-point, *c*, is also mounted on the beam. The beam is insulated from the plate by having the pivots of the shaft *S* turn in garnet jewels. The point *c* rests on a similar point, *c′*, mounted at the end of a screw of fine pitch, *M*, which screws into the post *K*, thus permitting the height of *c′* above *K* to be adjusted. The post *K* is screwed into the base-plate. *P* and *Q* are binding-posts; *Q* is in electrical connection with the base-plate, and *P* is insulated from it.

The current comes from one pole of the battery to the binding-post *Q*; from there through the base-plate to *K*; thence to *M* and to *c′*; then to *c* and to the beam, which is connected to the insulated post *P* by a fine copper wire. From *P*, the current passes through the sounder, or relay, to the other pole of the battery. When *c* rests on *c′*, the circuit is complete, and when *c* is lifted from *c′*, the circuit is broken.

The breaker is attached to the back of the clock-case, at a convenient distance—say about eighteen inches—below the suspension-spring, the plane of the beam *AB* being parallel to the plane of the pendulum's swing, and at such a distance behind it that the pendulum-rod clears the wheel by about ¼ inch. On the back of the pendulum-rod, and perpendicular to it, is a pin, *L* (figure 3), which engages the under side of the wheel at each vibration and slightly raises it, lifting *c* from *c′*, and breaking the circuit.

In figure 1, *v–w–x–y–z* is the path of the pin *L*. It will be seen that the arc of contact of *L* with the wheel is but a small part of the entire arc.

The action of the breaker is as follows: Starting with the pendulum at the extreme left point of its swing, the pin *L* being at *v*, it swings in the direction of the arrow, and the pin *L* comes in contact with the wheel when it arrives at *w*. From *w* to *y* the pin passes under the wheel, thereby lifting the beam through a small distance. This separates *c* and *c′*, and breaks the circuit. The pin leaves the wheel at *y*, and the circuit is again closed. The pendulum swings on to *z*, the extreme right point of its swing. On its return the action is repeated in reverse order.

The beam is lifted a constant distance each time the circuit is broken; the mass of the beam is constant; hence, constancy in the work required each time to break the circuit is secured.

Before trying the breaker in actual service on a clock, I made a series of experiments with it to determine the amount of work needed to operate it. These experiments were of two kinds: first, to determine what pressure between c and c' would insure a safe and certain electrical connection; and, second, to determine the amount of work required to operate it, by observing its effect on a freely swinging pendulum.

In order to determine the pressure between c and c', the breaker was placed under a balance, and a fine silk fibre was attached between the wheel and balance-arm in such a way that c and c' could be separated by putting a sufficient weight in the other balance-pan. By measuring the pressure corresponding to four different values of the counterpoise W, I obtained

$$P = 1.395 - 0.24\,W,$$

in which the pressure P and the counterpoise W are expressed in grams.

The breaker was then put in the circuit of a battery and sounder, and different counterpoises used to find the least pressure between c and c' which would give a safe electrical connection. A counterpoise of 5.13 grams was found to be the largest value of W permissible. This value of W, by the above equation, corresponds to $P = 0.16$ grams.

But, if we take the work done in breaking the contact as the raising of 0.16 grams through a space of 0.15 millimeters,— this being the amount of separation of c and c' at each vibration, — we shall find that this is greater than the actual work required. While it is true that the pendulum does that much work on the breaker while L goes from w to x, it is also true that while L goes from x to y the breaker does work on the pendulum, since the beam is then falling to its original position. A large part of the work required to break the circuit is, therefore, given back to the pendulum. It was with the view of determining what per cent of the work done on the breaker is given back to the pendulum that the following experiments were made.

A pendulum was made having a length of 77.3 cm. and a bob weighing 960 grams. It vibrated sixty-eight times a minute. A fine pointer was attached to the bottom of the bob, and a stationary scale was placed behind it. The arc of vibration was then read by means of a telescope at a distance of about twenty feet The arc of the pendulum's swing could be read with a probable error of not more than one minute of arc.

The pendulum was set swinging, and its arc of vibration read. After swinging freely for one hour the arc was again read. The arc had, of course, decreased, owing to the friction of the suspension-spring and the resistance of the air.

The breaker was then adjusted, and the pendulum again set swinging through the same arc as before. Readings were again taken at the beginning and end of the hour. The arc was further decreased, owing to the added resistance of the breaker.

At the end of the first hour the pendulum was swinging through an angle θ on either side of the vertical, and at the end of the second hour, during which the breaker had been in operation, through an angle ϕ. Evidently $\theta - \phi$ is the decrease in arc due to the resistance of the breaker during the hour, and the difference between the potential energy which the pendulum had at the angle θ and at ϕ is the energy which had been used in working the breaker one hour. The work done on the breaker is given by the expression

$$d\,(\cos\phi - \cos\theta)\ W',$$

in which W' is the weight of the bob, and d is the distance from the point of support to the center of gravity of the bob. All the quantities in this expression are known by measurement, and the work may, therefore, be computed.

In the first experiment, with the breaker off, at the beginning of the hour the arc of vibration of the pendulum on either side of the zero was 2° 36′, and at the end of the hour 1° 9′, giving a decrease of 1° 27′. With the breaker on, the reading at the beginning of the hour was 2° 37′; at the end of the hour 1° 4′, a decrease of 1° 33′. The decrease due to the breaker was 6′, and by the formula above the work done by the pendulum in working the breaker was 2.49 centimeter-grams.

By the second experiment, $\theta = 0^\circ\ 50'$, and $\phi = 0^\circ\ 42'$, and the work, as before, was 2.32 centimeter-grams. These two results agree well within the limits of accuracy of observation.

The pendulum made 4080 beats an hour. The force at the wheel was 0.16 grams. At each swing of the pendulum the feet long there will be plenty of space for a solar spectroscope nine feet long, and a dew-cap of about equal length. The shutter-opening is twelve feet wide. Adjustable canvas curtains will be provided to shield the telescope from the wind.

Warner & Swasey have also been awarded the contract for the rising floor. It is seventy-five feet in diameter and will have a vertical motion of twenty-two feet. Both the floor and dome will be moved by electric motors.

Of the two smaller domes, the one to the northeast will contain the twelve-inch telescope now at the Kenwood Observatory, and the other a sixteen-inch telescope. Between these domes is the heliostat room, one hundred feet long by twelve feet wide. The heliostat will stand on a pier at the north end of the room, under an iron roof which can be rolled away to the south.

The meridian room has double sheet-iron walls, with an intervening air space. The room is designed to contain a meridian circle of large aperture, but for the present a transit instrument will suffice for the purposes of the Observatory.

The body of the building is divided through the center by a hallway extending from the meridian room to the great tower. On either side are offices and computing rooms, a library, lecture room, spectroscopic laboratory, optical room, dark room, developing room, galvanometer room, chemical laboratory, instrument rooms, etc. In the basement is a large photographic dark room, an enlarging room, concave grating room, emulsion room, constant-temperature room, and physical laboratory.

The building is constructed of gray Roman brick, with gray terra-cotta and stone timmings. It is situated in the midst of a large tract of land on the shores of Lake Geneva, Wisconsin (about seventy-five miles from Chicago), at an elevation of 180 feet above the lake. The architect is Mr. Henry Ives Cobb, of Chicago.

The engines, dynamos and boilers for supplying power and heat are to be at a distance of several hundred feet from the Observatory. In the small building that contains them will also be the shops for the construction and repair of special instruments and apparatus.—Reprinted from the *Astro-Physical Journal* for June, 1895, with a few corrections by the author.

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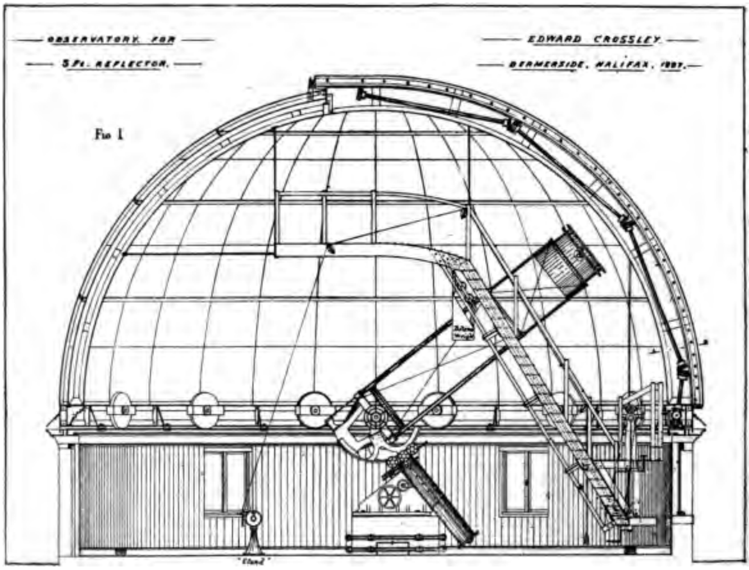

THE CROSSLEY REFLECTOR.

Monthly Notices of Royal Astronomical Society

NOTICES FROM THE LICK OBSERVATORY.

Prepared by Members of the Staff.

Corner-Stone of the Crossley Dome.

A small zinc box has been built into the walls of the Crossley Dome. It contains a letter of Mr. Crossley; the cards of the astronomers of the Lick Observatory; the circular to visitors, of the Lick Observatory Committee of the Regents; a circular of the Astronomical Society of the Pacific; and a set of United States postage stamps of the current year, and of the Columbian year, 1892. E. S. H.

Lick Observatory, July 4, 1895.

View of the Lick Observatory.

The view of the Lick Observatory, which is the frontispiece of the present number, is reduced from a pencil sketch made by Mr. Peano, Instructor in the Lick School of Mechanic Arts in San Francisco, and presented to the Lick Observatory. Our California members will need no key to the drawing. To those who have not visited Mount Hamilton, the following brief explanation may be of service:

The main observatory, with the great dome at the left (south), the dome of the twelve-inch equatorial at the right (north) is on the summit of Mount Hamilton.

The lower peak, on the left-hand of the picture, is *Mount Ptolemy*, whose highest point is about 130 feet lower than Mount Hamilton and about 1000 feet southwards from it.

The Crossley Dome is shown on the extreme left-hand of the cut, as if it were completed. In fact, it only lacks the hemispherical iron dome which is on its way from England at the time of writing. The brick cottage just north of the CROSSLEY Dome is occupied by Professor CAMPBELL, and the second brick cottage near it by Professor BARNARD.

The windmill and reservoir just below the great dome are on the summit of *Mount Huyghens*. Just to the south of this reservoir is the CROCKER photographic telescope and observatory. The SCHAEBERLE eighteen-inch reflector is not shown in the picture. It is mounted on a hill in front of the foreground, whose summit is some 1000 feet from the large dome.

The roadway starts from the rear side (in the picture) of the main building, then winds around the left-hand (south) side of Mount Hamilton, thence round Mount Hamilton to the north, and disappears at the right of the picture. It then passes back of Mount Hamilton, and reappears in the picture as the lower road on *Mount Ptolemy*. The upper roadway leads up to and around the CROSSLEY Dome. E. S. H.

APPOINTMENTS AND RESIGNATIONS IN THE LICK OBSERVATORY.

At a meeting of the Regents of the University of California, held June 11, 1895, the resignation of Professor BARNARD was received and accepted, to date from October 1, 1895. Professor BARNARD has been called to the position of Professor of Astronomy in the University of Chicago.

At a meeting of the Regents, held July 9th, the following appointments were made:

Professor WM. J. HUSSEY, now head of the department of astronomy in the STANFORD University, to be Astronomer in the LICK Observatory, to date from January 1, 1896; Professor ROBERT G. AITKEN, now head of the department of astronomy in the University of the Pacific, to be Assistant Astronomer in the LICK Observatory, to date from August 1, 1895. E. S. H.

FALL OF A LARGE METEOR.

The newspapers report a large meteor as having fallen in a lagoon near Chimacum, a farming hamlet four miles from Port Townsend, Washington, at 8 P.M., June 15, 1895. The meteor burst a short distance above the earth with a loud explosion, the concussion breaking crockery in the neighborhood. The water in the lagoon was warm for some hours after. C. D. P.

LARGE METEOR, JUNE 22, 1895.

Dr. BARRICKMAN, writing from Red Bluff, notifies the L. O. of a meteor which appeared about midnight of Saturday, June 22d, between *Cassiopea* and *Polaris*, and, passing below *Ursa Major*, moved upward and disappeared.

THE ILLUSTRATIONS OF THE PRESENT NUMBER.

The Committee on Publication have thought it desirable to reprint, in the present number of the *Publications*, some of the illustrations which have appeared in the past volumes, 1888–1894, together with other new ones, believing that this collection will be particularly interesting to members who have but recently joined the Society, and not unwelcome to any.

THE COMMITTEE.

REMARKABLE METEOR (JULY 10, 1895,).—NOTE BY PROFESSOR WILLIAM P. BLAKE.

About eight o'clock, railway time, in the evening of the 10th of July, a brilliant meteor of unusual magnitude passed over Northern Sonora, Mexico, in a general southwesterly direction from near the zenith to within about 15° of the horizon, where it suddenly disappeared. There was no accompanying sound or noise of a body rushing through the air, and after the disappearance of the meteor, presumably by explosion, an expected report or detonation was not heard until four or five minutes later, when there was a very heavy report, as if made by the explosion of a magazine or heavy ordnance, sufficient to shake the building and make the windows rattle. The interval between the sudden disappearance of the meteor and the report was so long that the time was not noted except by estimate, which placed it at five minutes. Using this as a factor in a calculation of the distance, this distance must have been sixty miles southwest of the point of observation at El Grupo, or about forty-five miles south of El Plomo, a village north and west of Altar.

During the passage of the meteor, the heavens were brilliantly lighted up with a bluish-green light. Trees and rocks and small objects upon the earth became distinctly visible. The fact of some extraordinary combustion was first made known by this weird light, and looking upward the blazing meteor was seen rushing southward and westward. It apparently had a solid head, or nucleus, about one-third of the Moon's diameter in size, as it appears to the eye, but in a state of vivid combustion, marked by the strong white light, and leaving behind it a comparatively short conical train of light or fire, the length being about ten times the seeming diameter of the nucleus. This conical train was distinctly tipped with a bright red light like that produced by burning strontium. This red coloration was very strongly marked, and was noted by several persons. There were no sparks or scintillations.

This meteor was remarkable for its size, intensity of light, the red light, and for the volume of sound produced by its explosion, sufficient to produce a startling concussion at a distance of sixty miles or more.

District of Altar, Sonora, Mexico, July 11, 1895.

Bright Meteor, July 17, 1895.

While observing with the meridian-circle, about midnight of July 17th, a meteor of the brightness of a second-magnitude star was seen to traverse the opening of the south shutter. The altitude was about 30°; the direction from east to west, slightly upward, and the trail, which was bright, vanished within a few seconds.

The time was recorded on the chronograph, and was, in Pacific standard time, $12^h\ 7^m\ 11^s$. R. H. T.

Notice to Correspondents of the Astronomical Society of the Pacific and of the Lick Observatory.

Small parcels destined for the A. S. P. or for the L. O. may be delivered to

H. Grevel & Co., 33 Kings Street, Covent Garden, London;
H. Le Sandier, 174 Boulevard St. Germain, Paris;
B. Herrmann, 2 Thalstrasse, Leipzig;

to be forwarded Care of B. Westermann & Co., 812 Broadway, New York City, in cases where the agents of the Smithsonian Institution cannot receive the packages. No articles subject to United States customs' duties can be so sent, however.

E. S. H.

ERRATUM IN NO. 42, VOL. VII, PAGE 141.

Mr. STETEFELDT points out that, through a mistake not his, the following correction is required on page 141:

For expulsion, *read* extraction. Commercial extraction is meant.
E. S. H.

ASTRONOMICAL NOTES.

Professor C. L. DOOLITTLE, for many years in charge of Department of Mathematics and Astronomy, Lehigh University, Bethlehem, Pa., has accepted a call to the University of Pennsylvania, as Director of the new observatory and Dean of the scientific faculty. The new observatory will be located about five miles west of the Philadelphia courthouse. Its equipment will consist of an eighteen-inch equatorial, four-inch zenith telescope, four-inch meridian circle, and three-inch prism transit. The contract for the entire equipment has been awarded to WARNER & SWASEY. J. A. BRASHEAR will furnish all the optical parts and the spectroscope.

Professor LEAVENWORTH, of University of Minnesota, is to be congratulated on having secured a telescope with a BRASHEAR ten and one-half-inch objective. This instrument will be a combination visual and photographic. The contract for the equatorial mounting has been awarded to WARNER & SWASEY, who expect to have the telescope in position in the early autumn.

The State University at Columbus, Ohio, has ordered from WARNER & SWASEY one of their most improved equatorial telescopes of twelve-inch aperture with BRASHEAR objective. BRASHEAR also makes the spectroscope.

ARRIVAL OF THE CROSSLEY REFLECTOR AT MOUNT HAMILTON.

The mirrors of the CROSSLEY Reflector left Liverpool on June 28th, and were delivered at Mount Hamilton in perfect order by WELLS, FARGO & Co's Express on July 18th.

The mounting of the telescope left Liverpool at the same time, and was safely delivered at Mount Hamilton on August 4th by the Southern Pacific R. R. Co. The forty-foot iron dome left Liverpool on July 26th, and is expected here about September 1st.
E. S. H.

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NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the *calendar* year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our book-keeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific 819 Market Street, San Francisco.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 819 Market Street, San Francisco, who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed rests with the writers, and is not assumed by the Society itself.

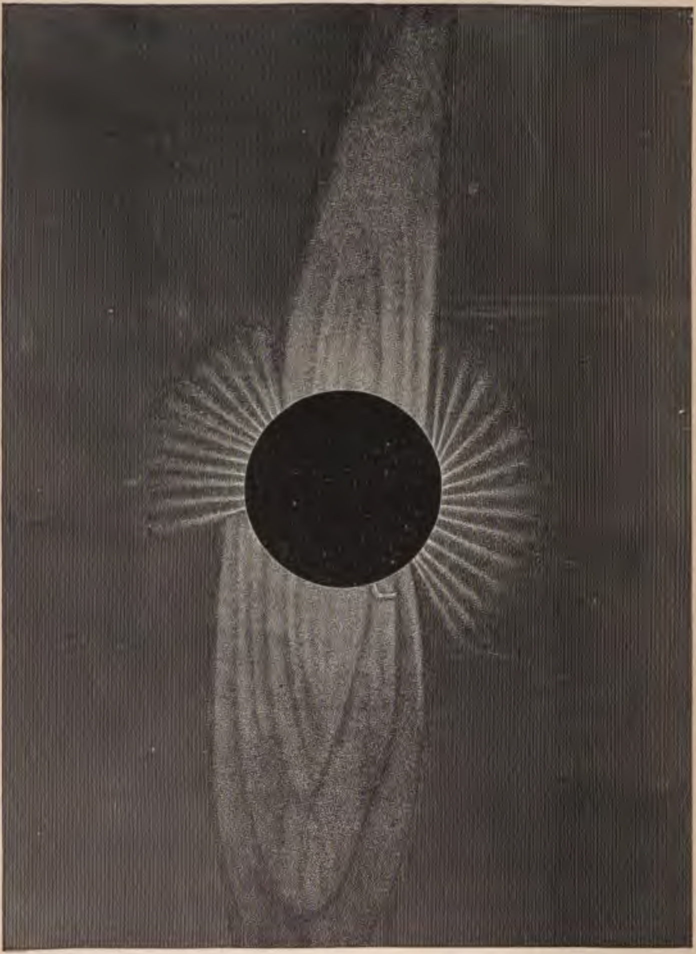
The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend any or all of the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific" at the rooms of the Society, 819 Market Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

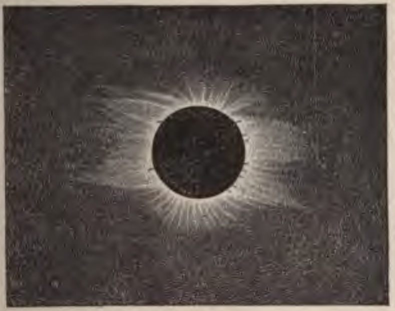
PUBLICATIONS ISSUED BI-MONTHLY.

JAMES LICK.

1796 - 1876.

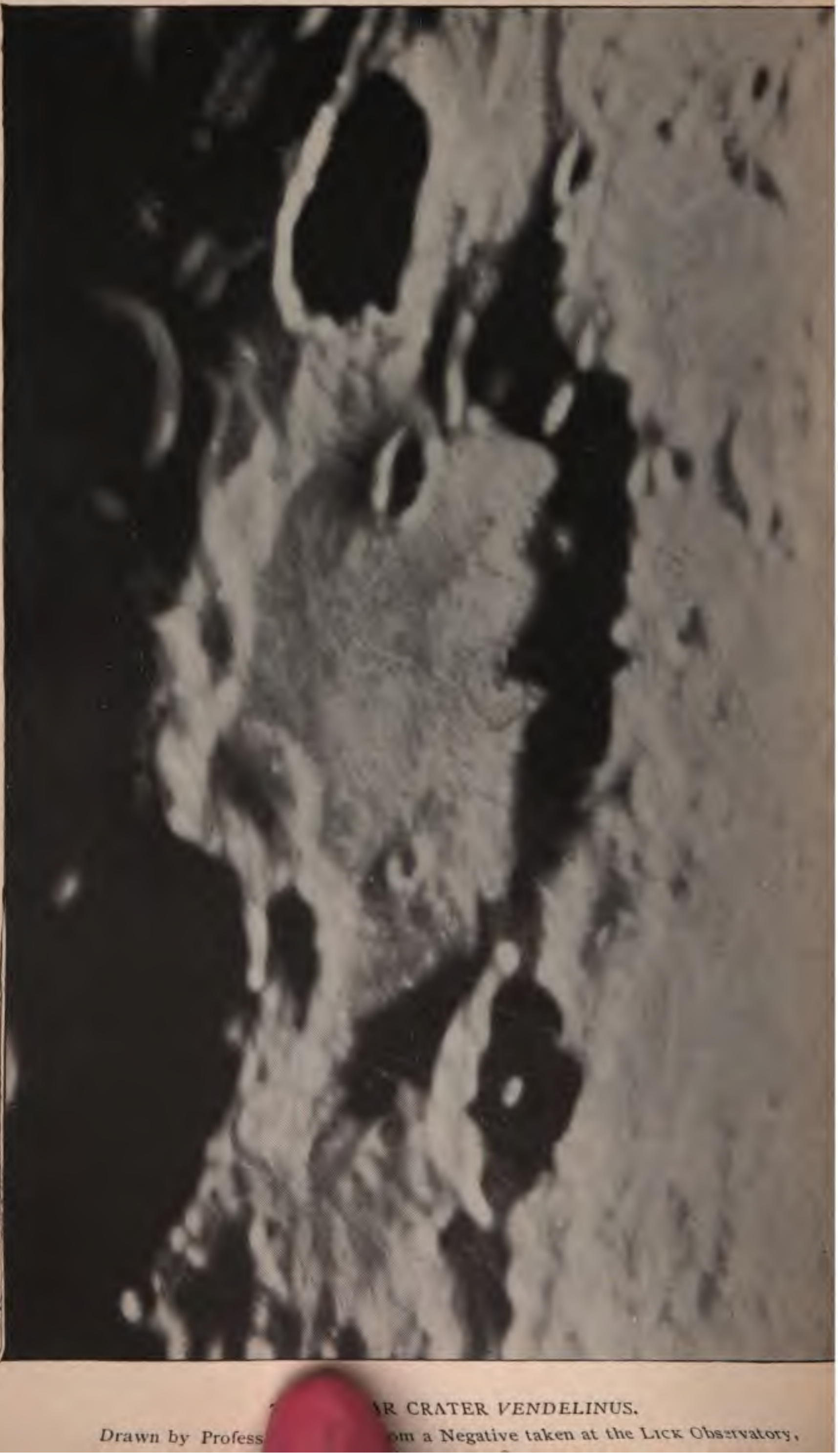


DRAWING OF THE SOLAR CORONA OF 1878.
BY L. TROUVELOT.



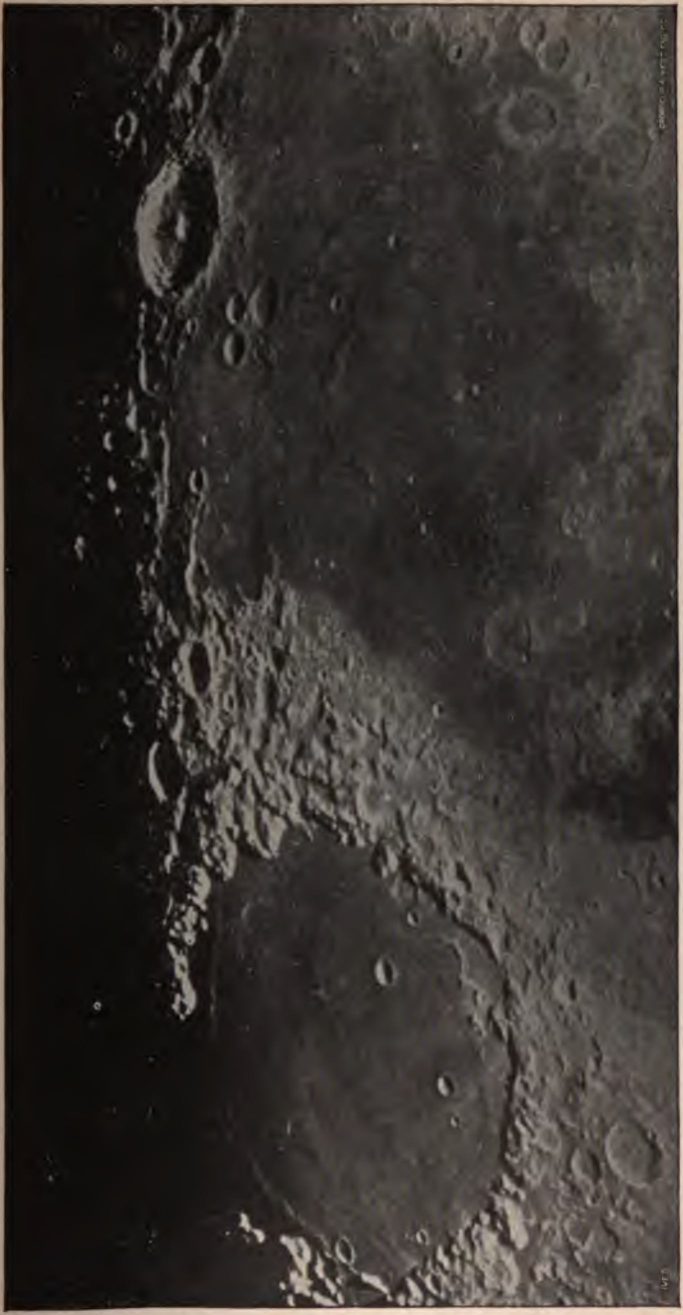
THE SOLAR CORONA OF JANUARY, 1889.

From Photographs by the Parties of the LICK Observatory
and of the Washington University.



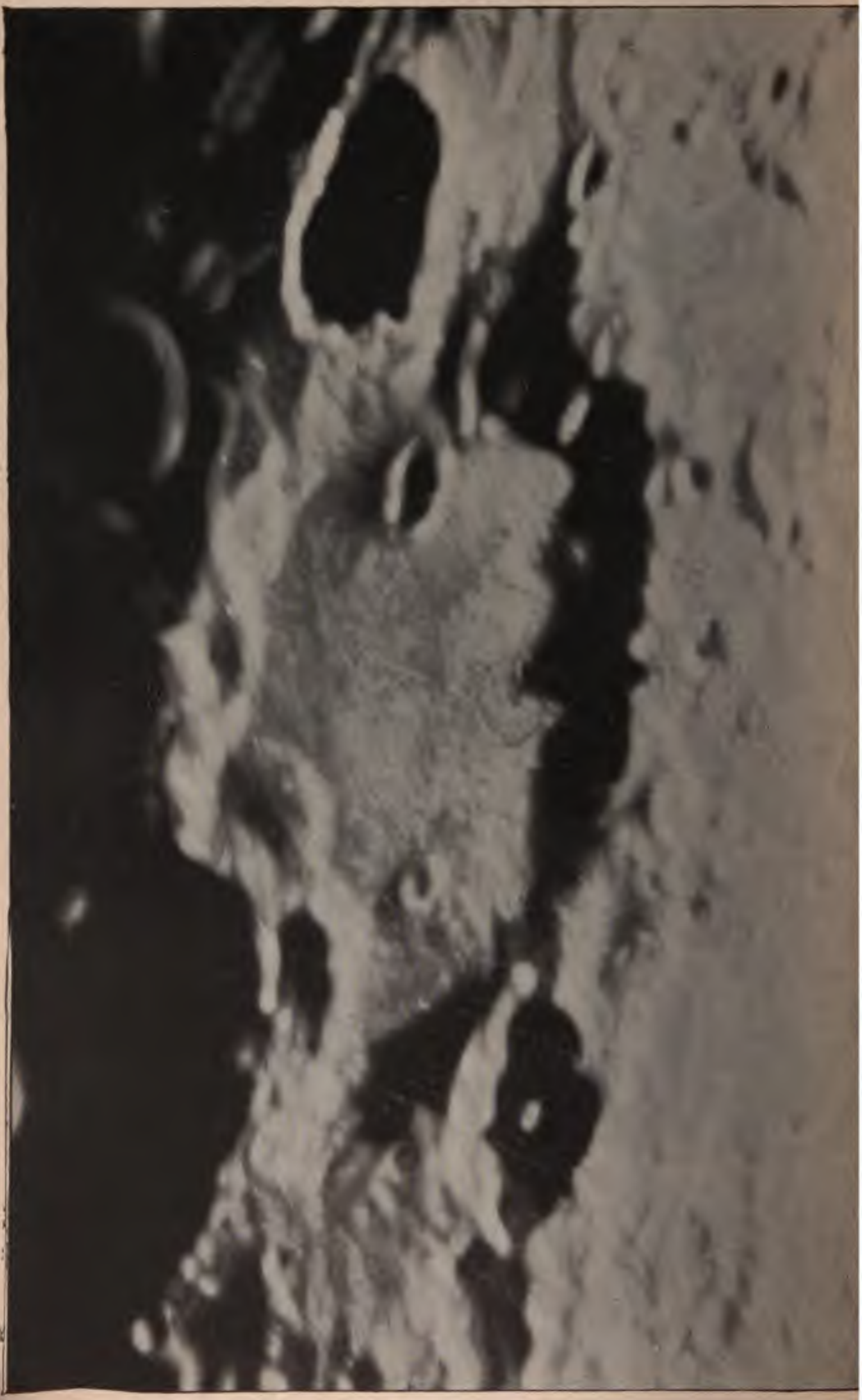
[illegible]R CRATER *VENDELINUS.*

Drawn by Profess [illegible] om a Negative taken at the Lick Observatory,



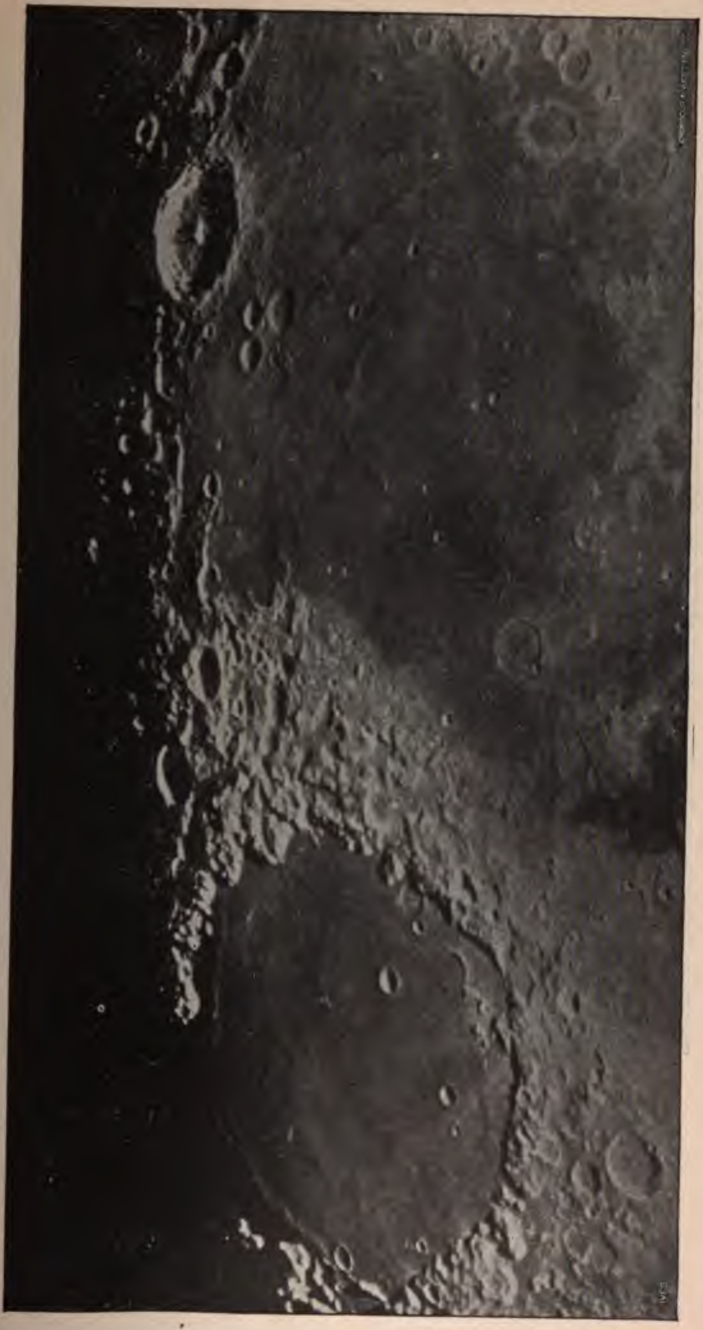
THE MOON.

Photographed at the Lick Observatory, August 31, 1890.



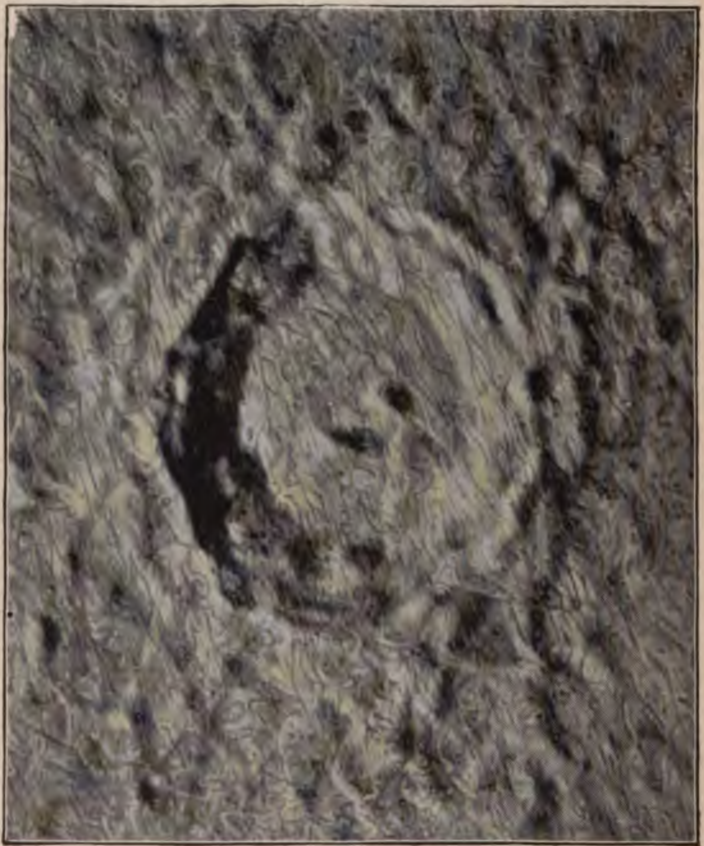
THE LUNAR CRATER *VENDELINUS.*

Drawn by Professor WEINEK from a Negative taken at the LICK Observatory.



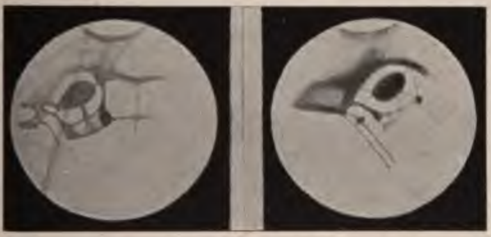
THE MOON.

Photographed at the LICK Observatory, August 31, 1890.



THE LUNAR CRATER *COPERNICUS.*

Drawn by Professor WEINEK from a Negative taken at the LICK Observatory, July 28, 1891.

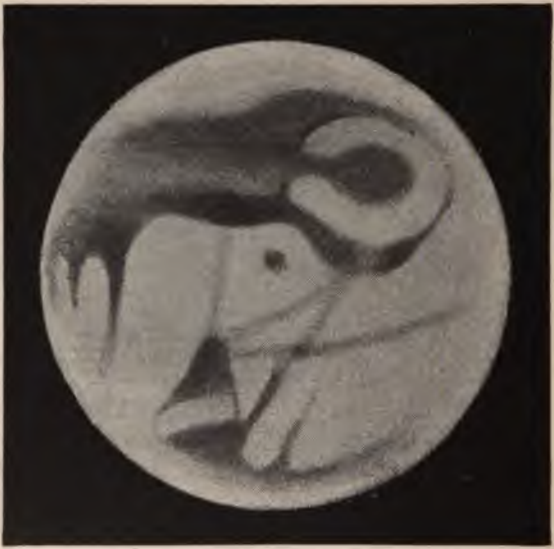


I. II.

1892, Aug. 14d 11h 15m, P.S.T. 1892, Aug. 17d 11h 15m, P.S.T.

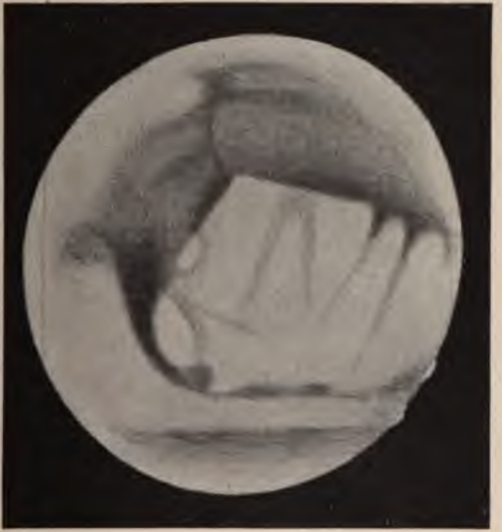
SKETCHES OF *MARS*, SHOWING CANALS.

I.—W. W. C. II.—W. J. H.



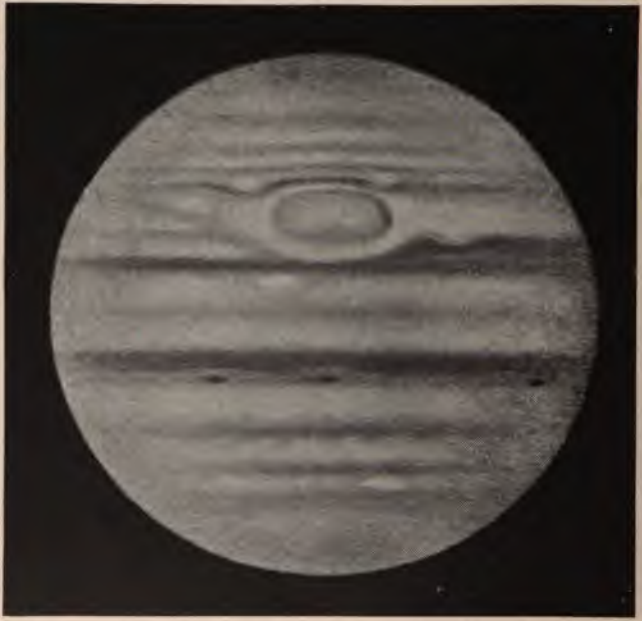
MARS.

May 21, 1890. E. S. H.



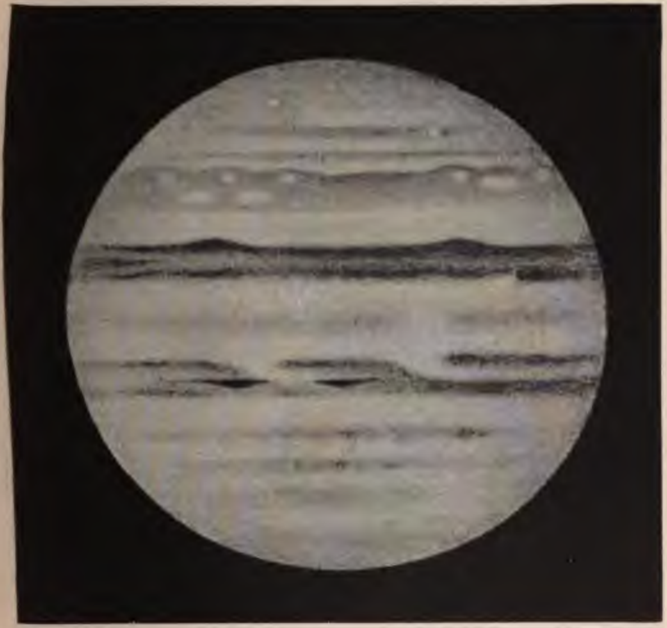
MARS.

July 6, 1890. J. E. K.



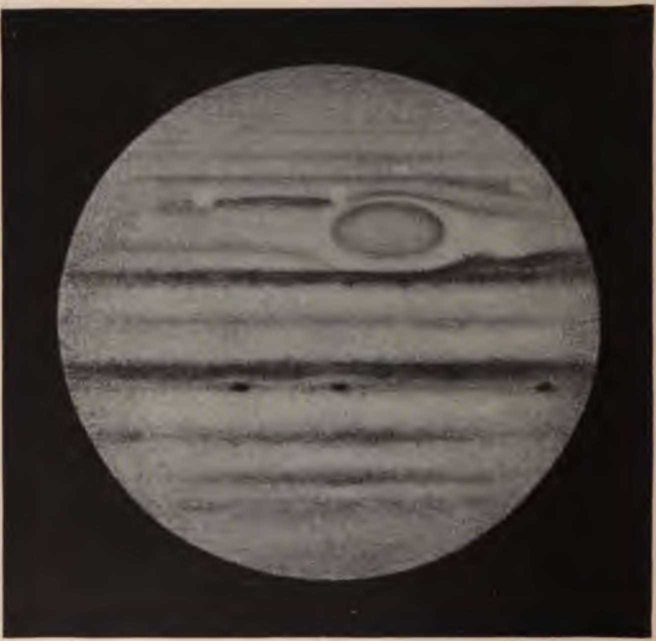
JUPITER.

October 3, 1890. J. E. K.

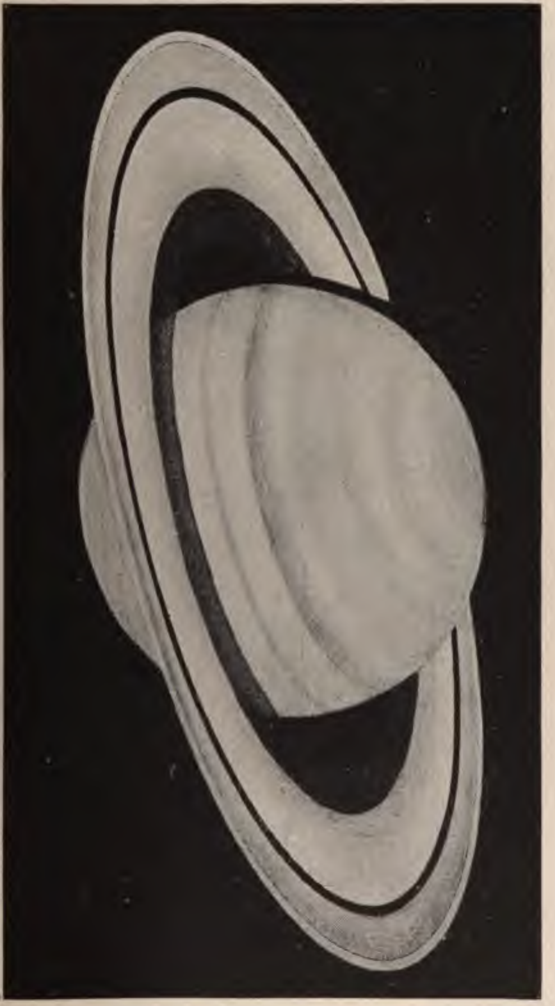


JUPITER.

July 10, 1889. J. E. K.

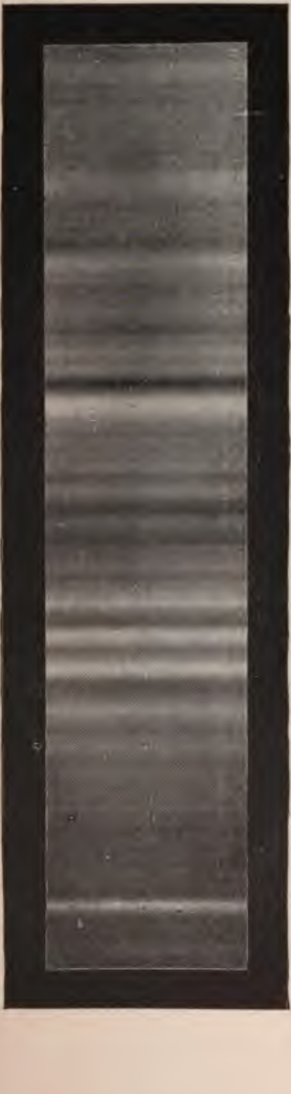


JUPITER.
August 28, 1890. J. E. K.

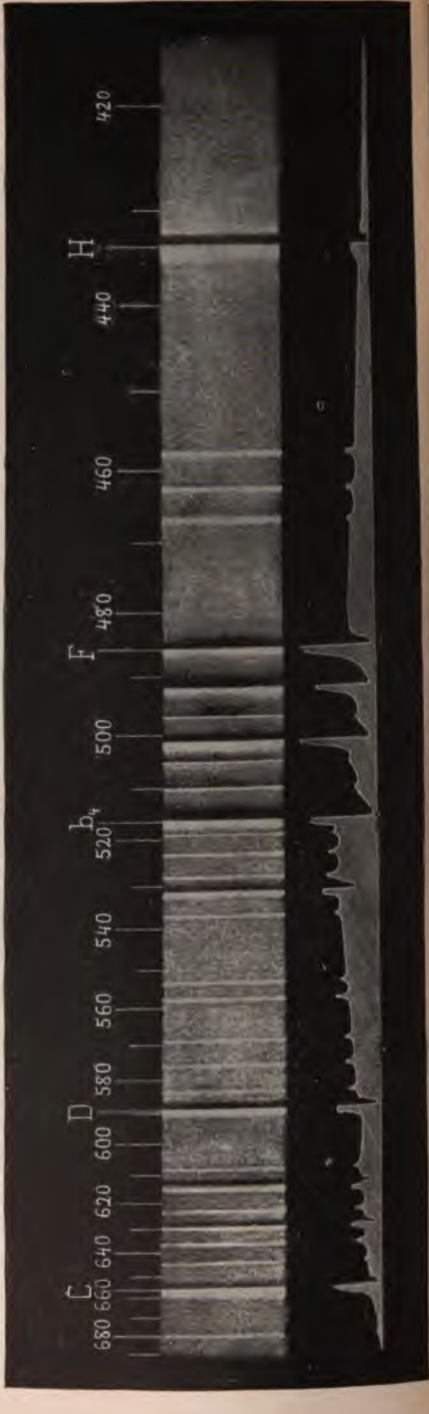


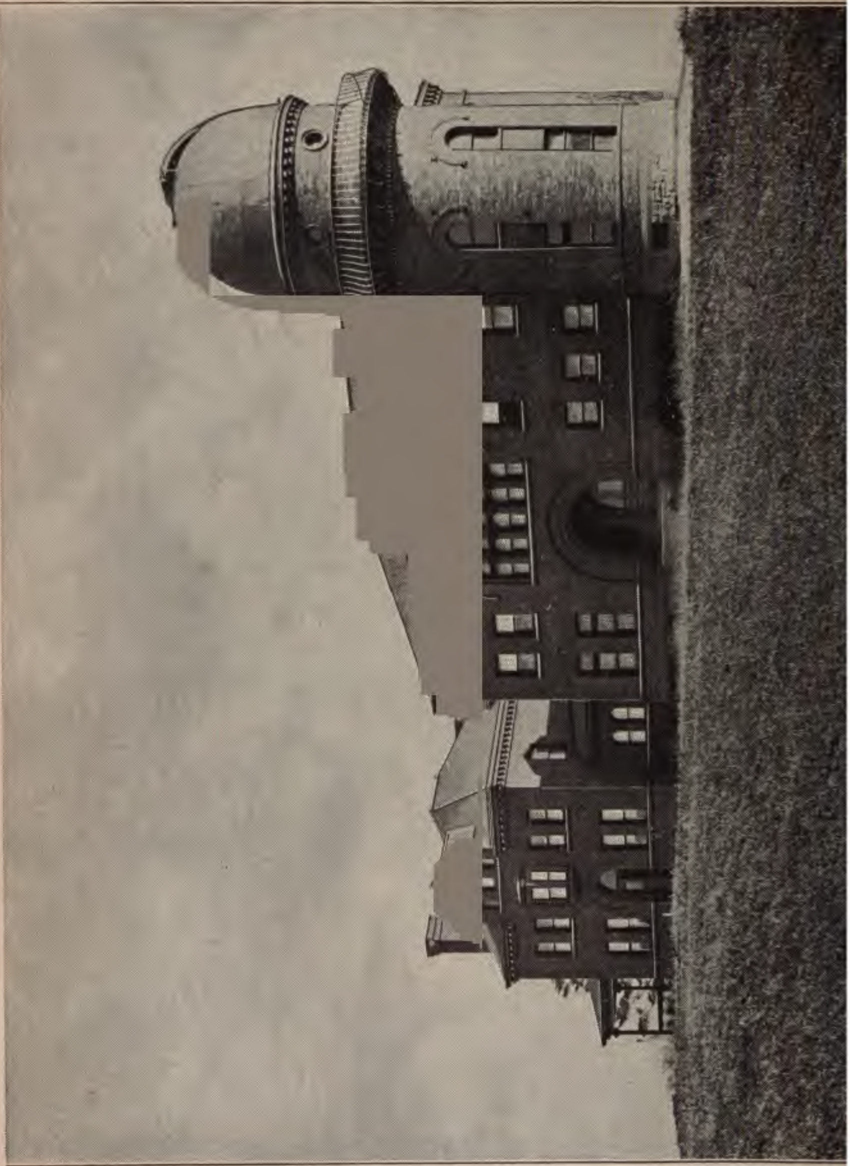
SATURN.

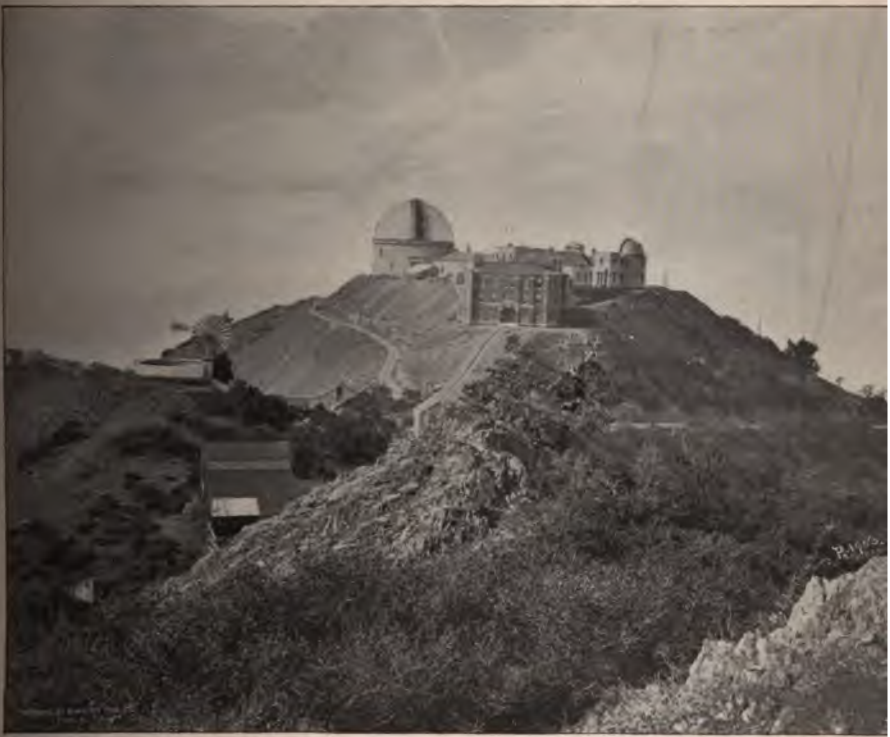
January 7, 1888. J. E. K.



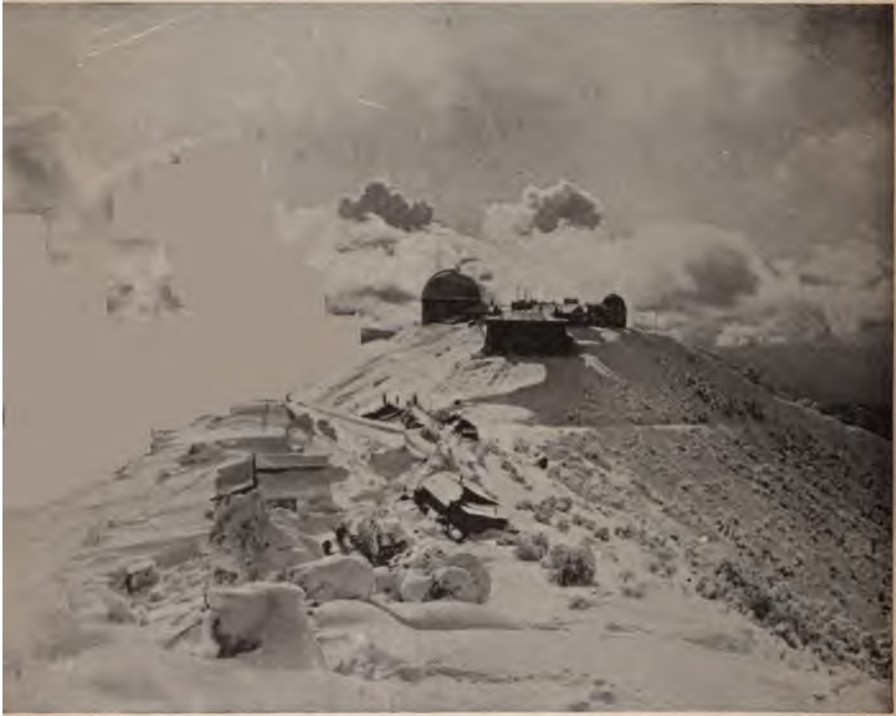
PHOTOGRAPHIC SPECTRUM OF THE NEW STAR IN *AURIGA*, 1891. W. W. C.







LICK OBSERVATORY.



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LICK OBSERVATORY IN WINTER.

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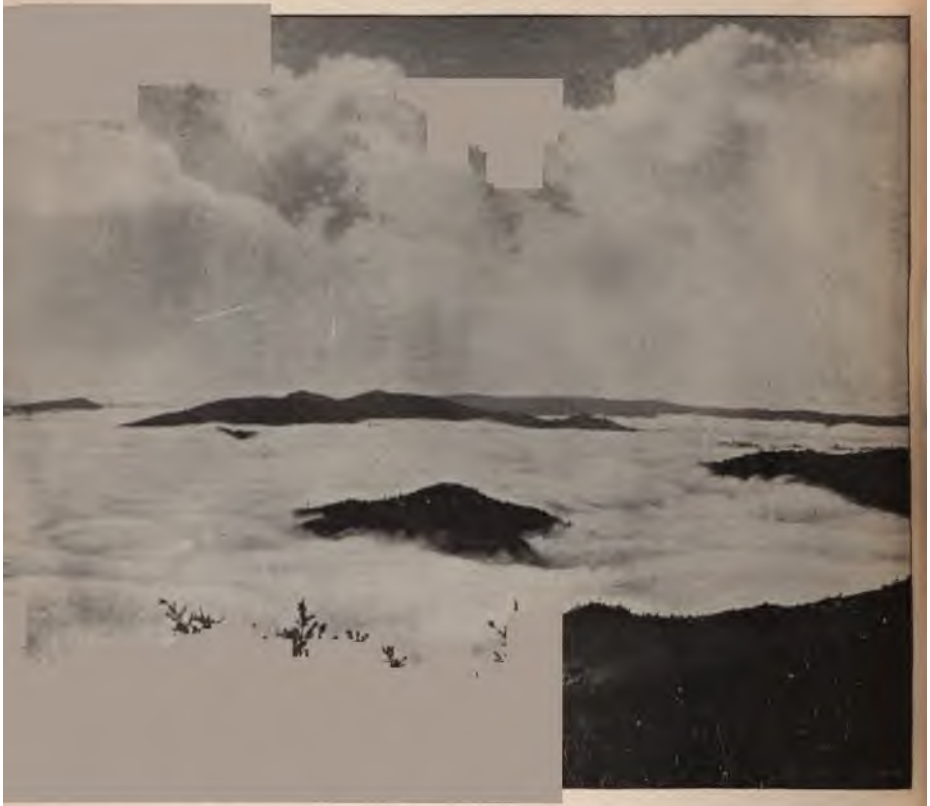
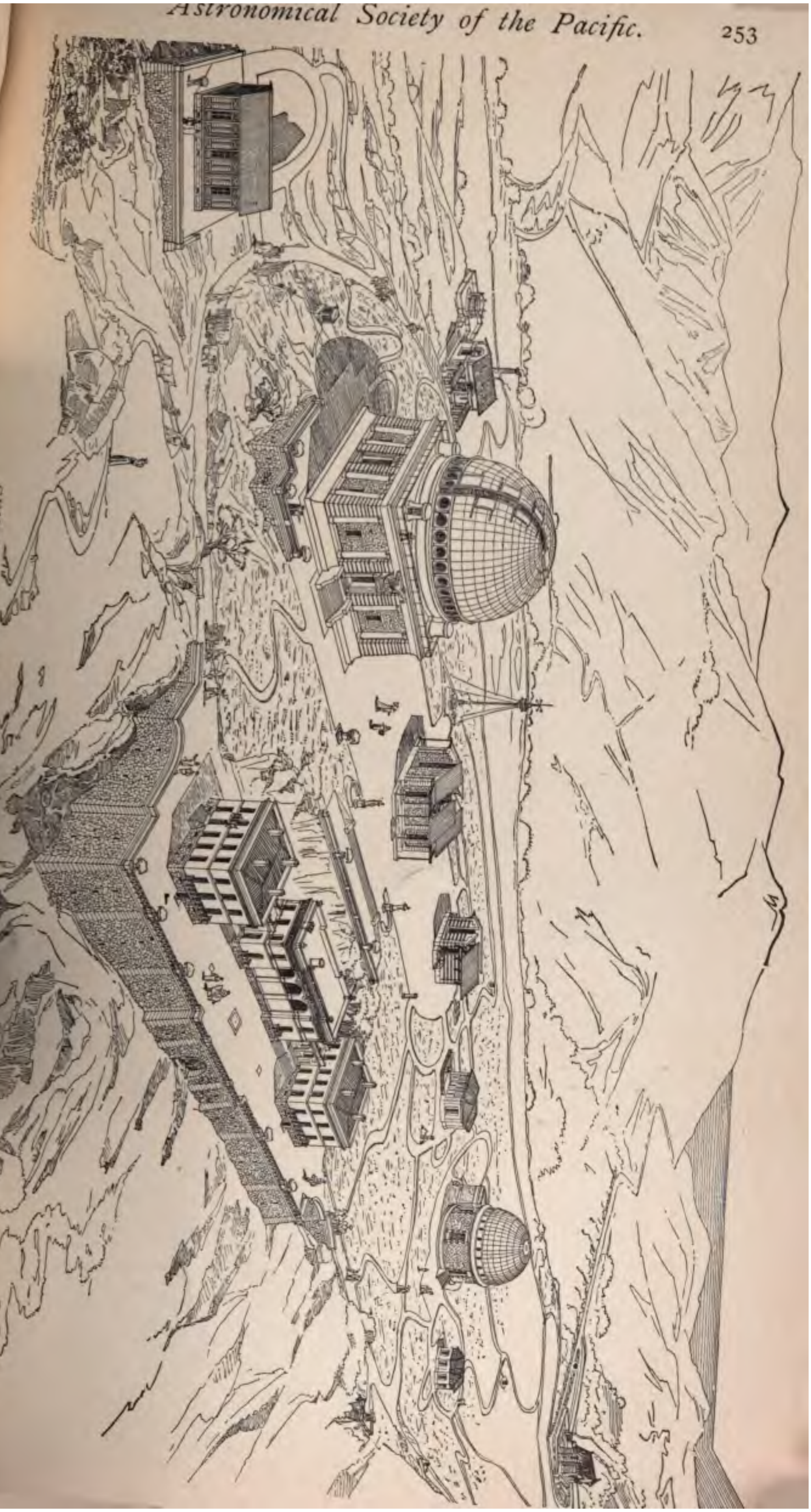
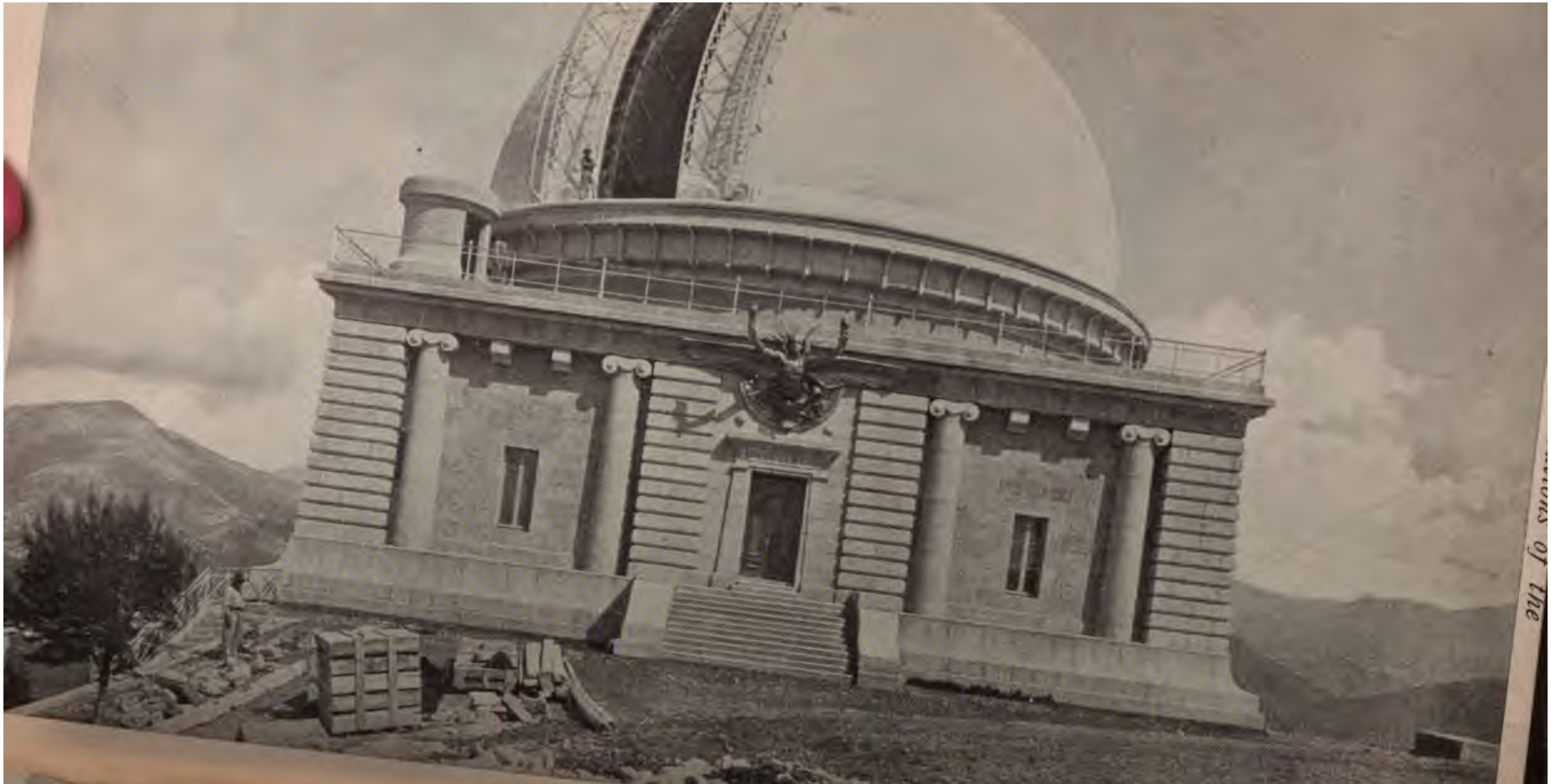
LICK OBSERVATORY—NIGHT SCENE.



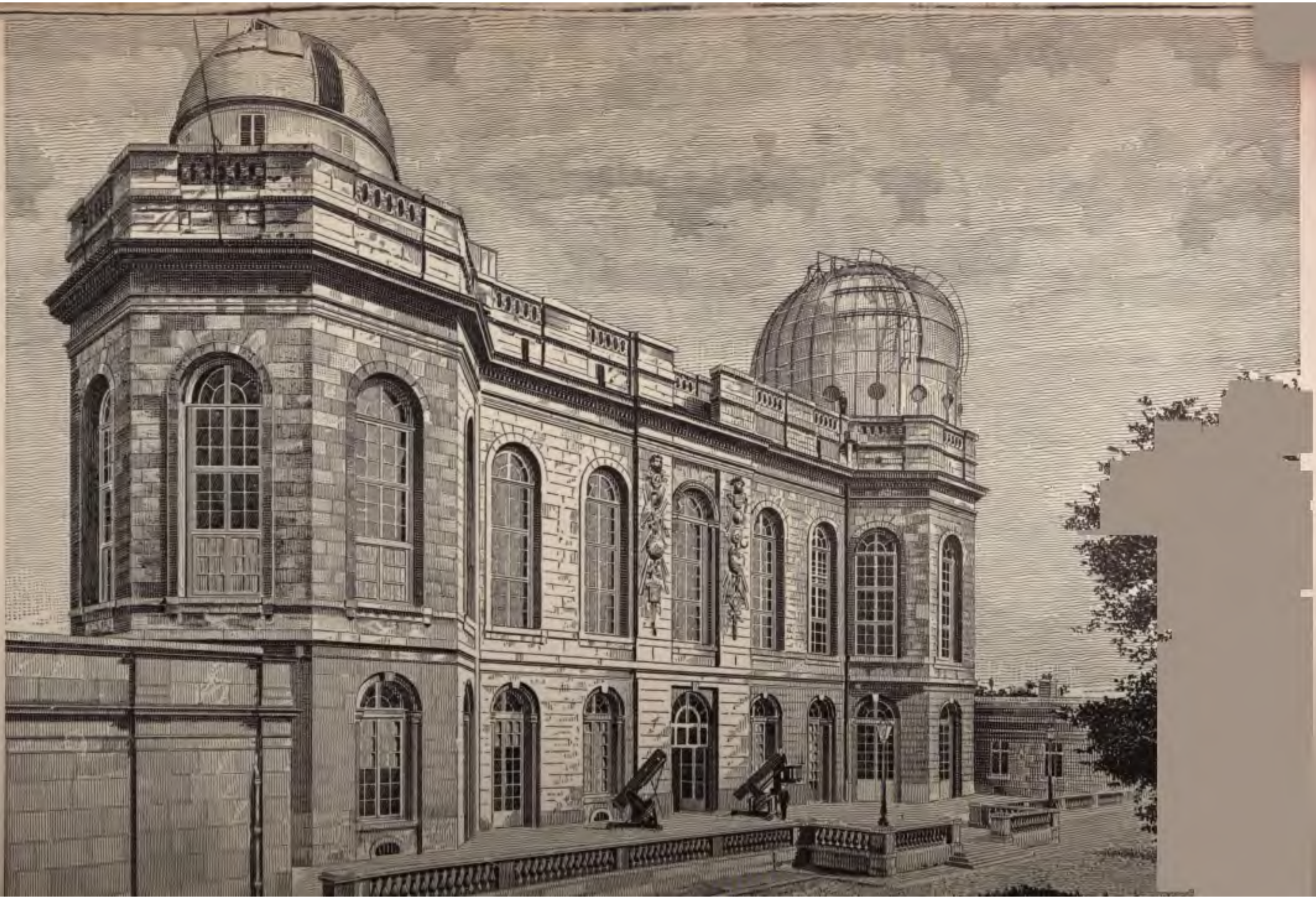
FOG IN THE VALLEYS NEAR MOUNT HAMILTON.

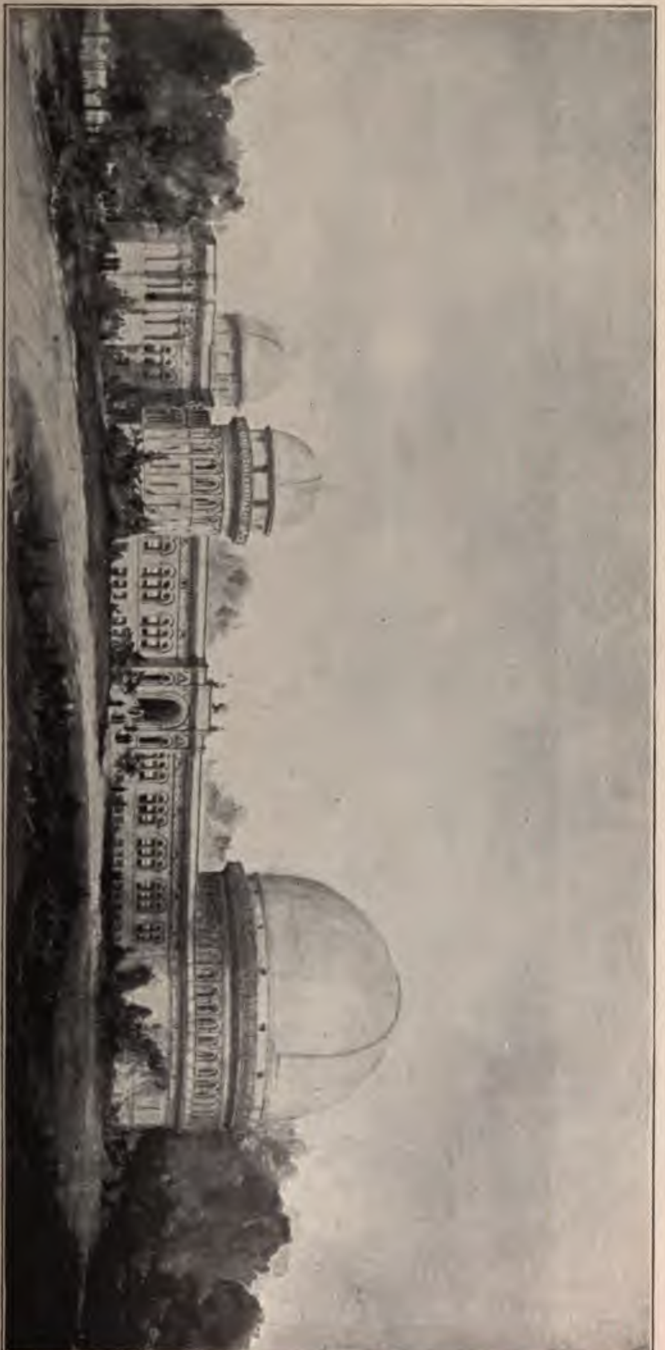


GENERAL VIEW OF THE OBSERVATORY OF NICE.

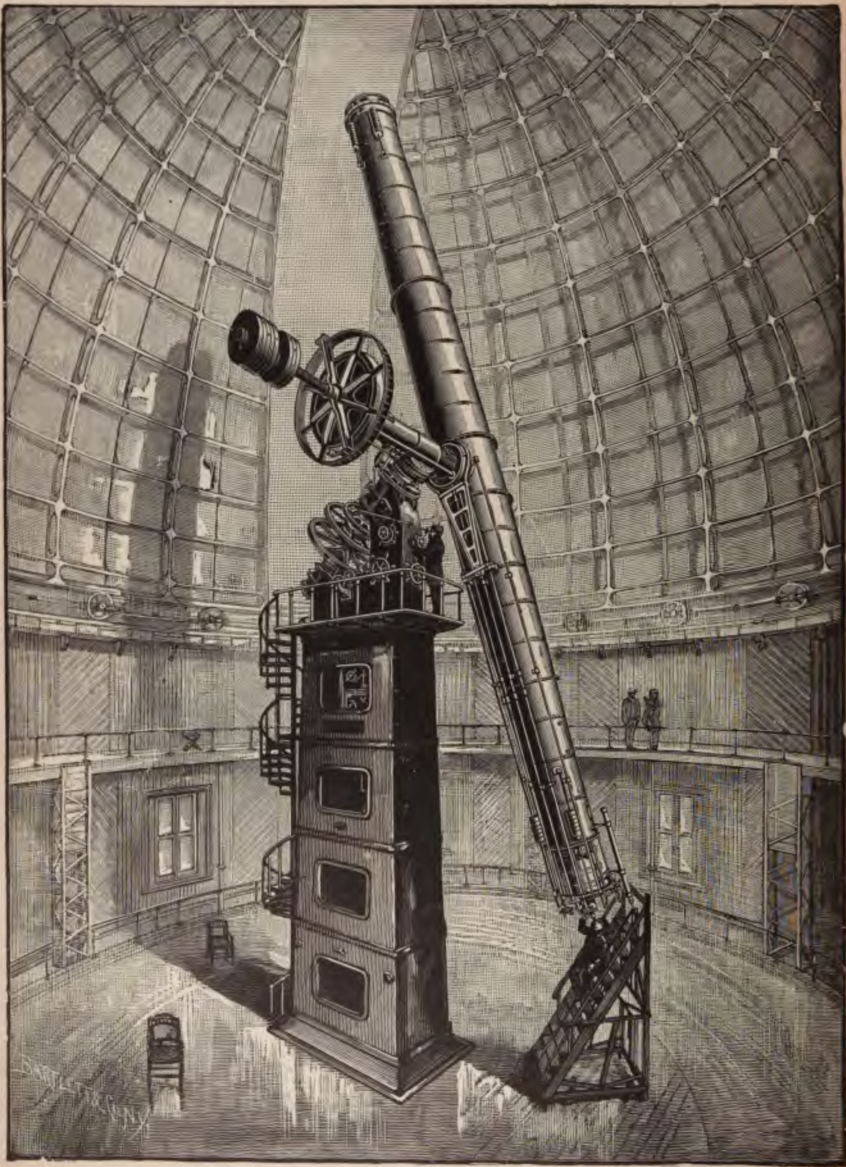


GREAT DOME OF THE OBSERVATORY OF NICE.

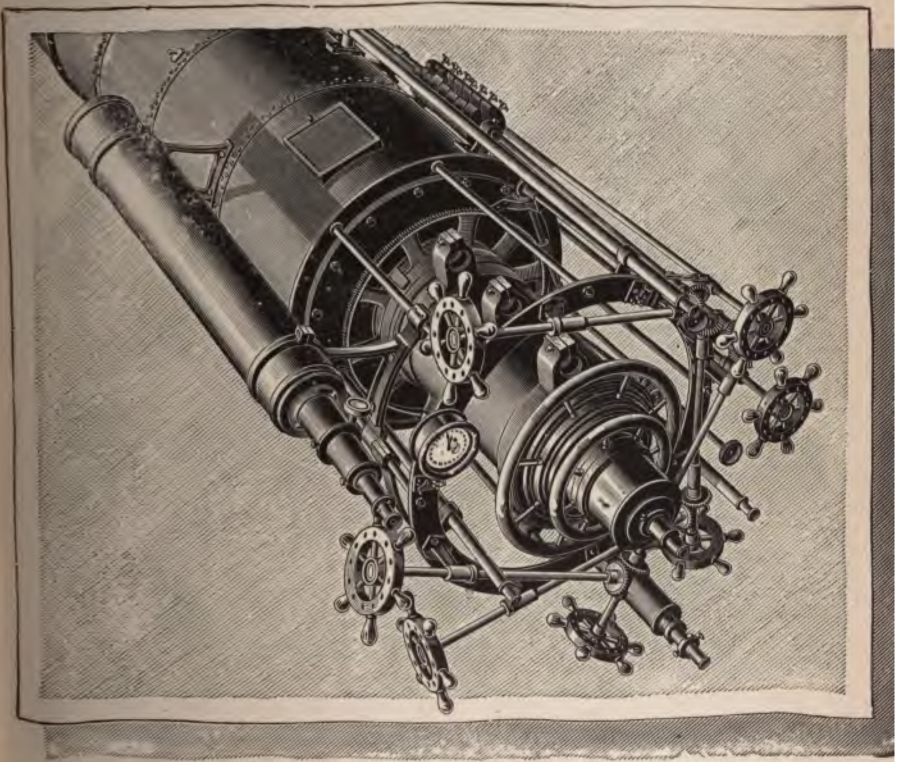




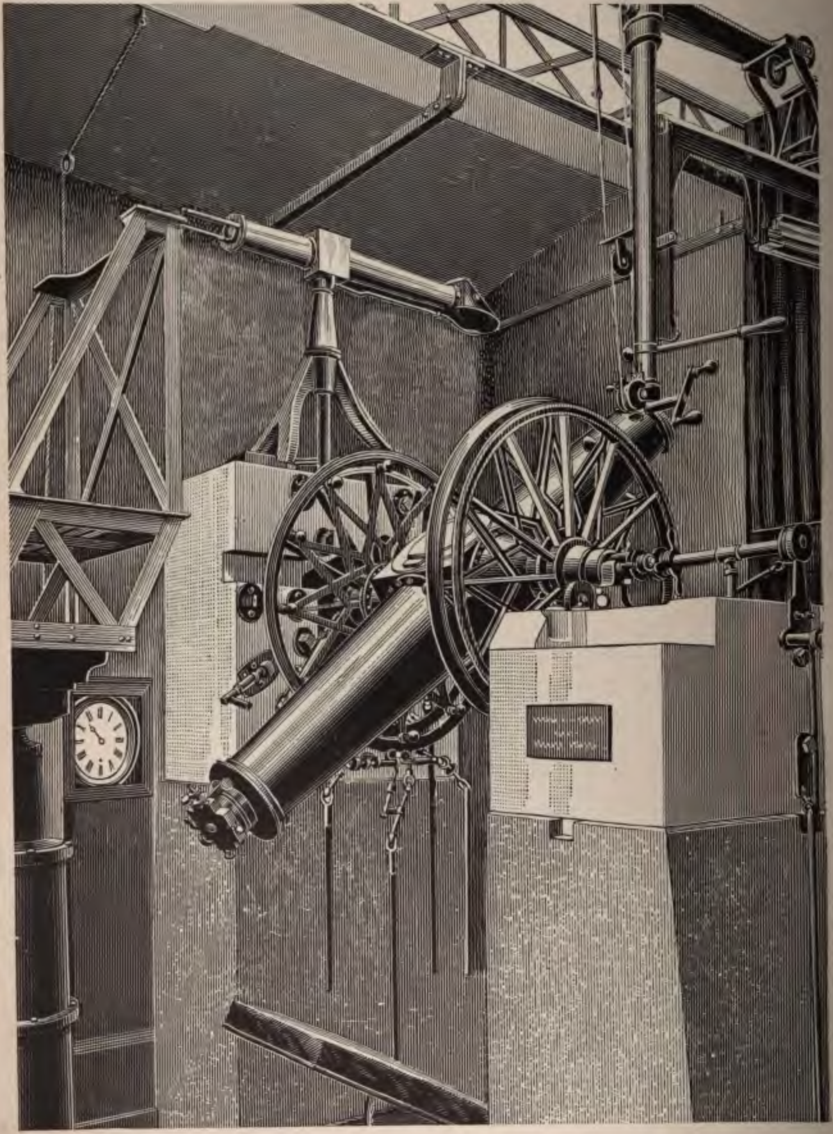
THE YERKES OBSERVATORY, LAKE GENEVA, WISCONSIN.



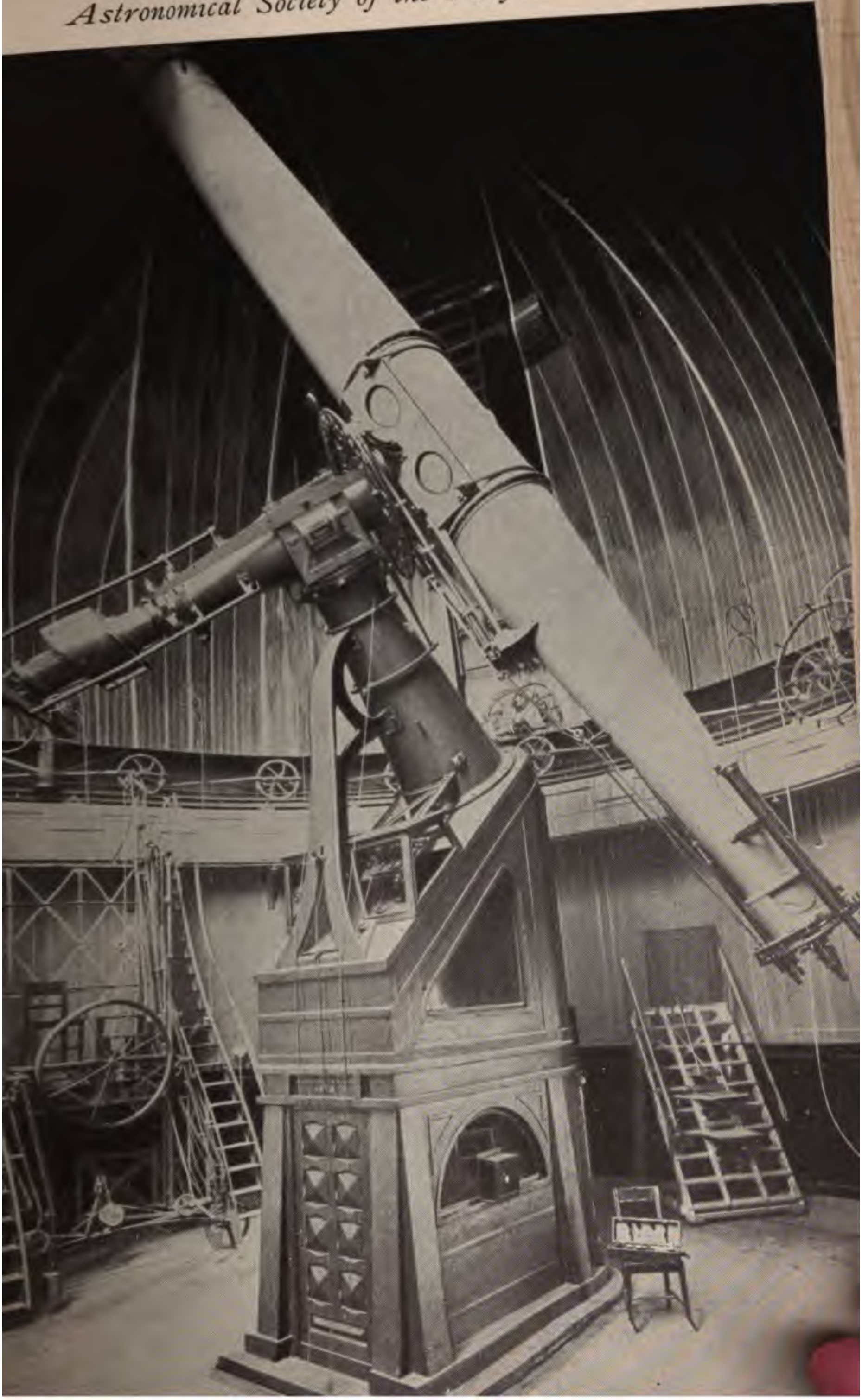
THE THIRTY-SIX-INCH REFRACTOR, LICK OBSERVATORY.

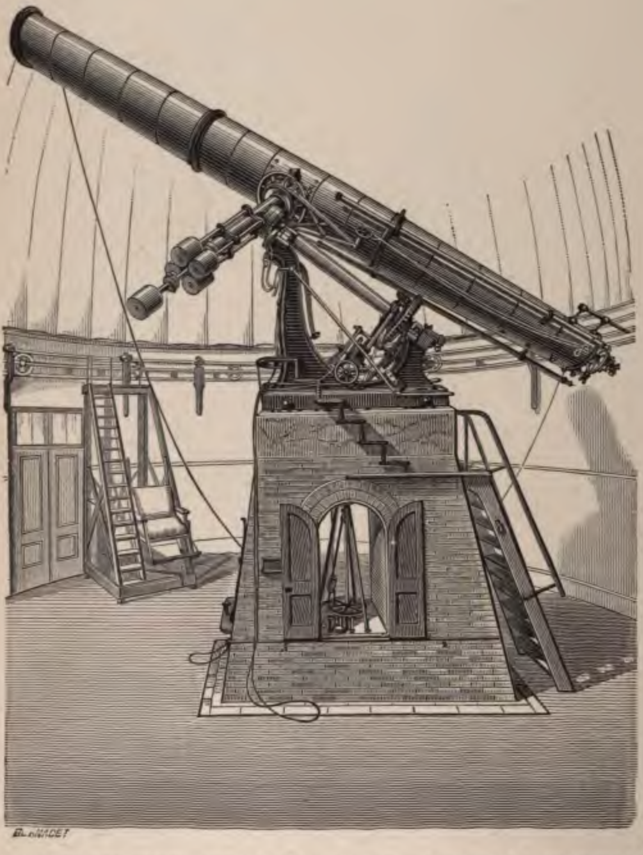


EYE-END OF THE THIRTY-SIX-INCH REFRACTOR, LICK OBSERVATORY.

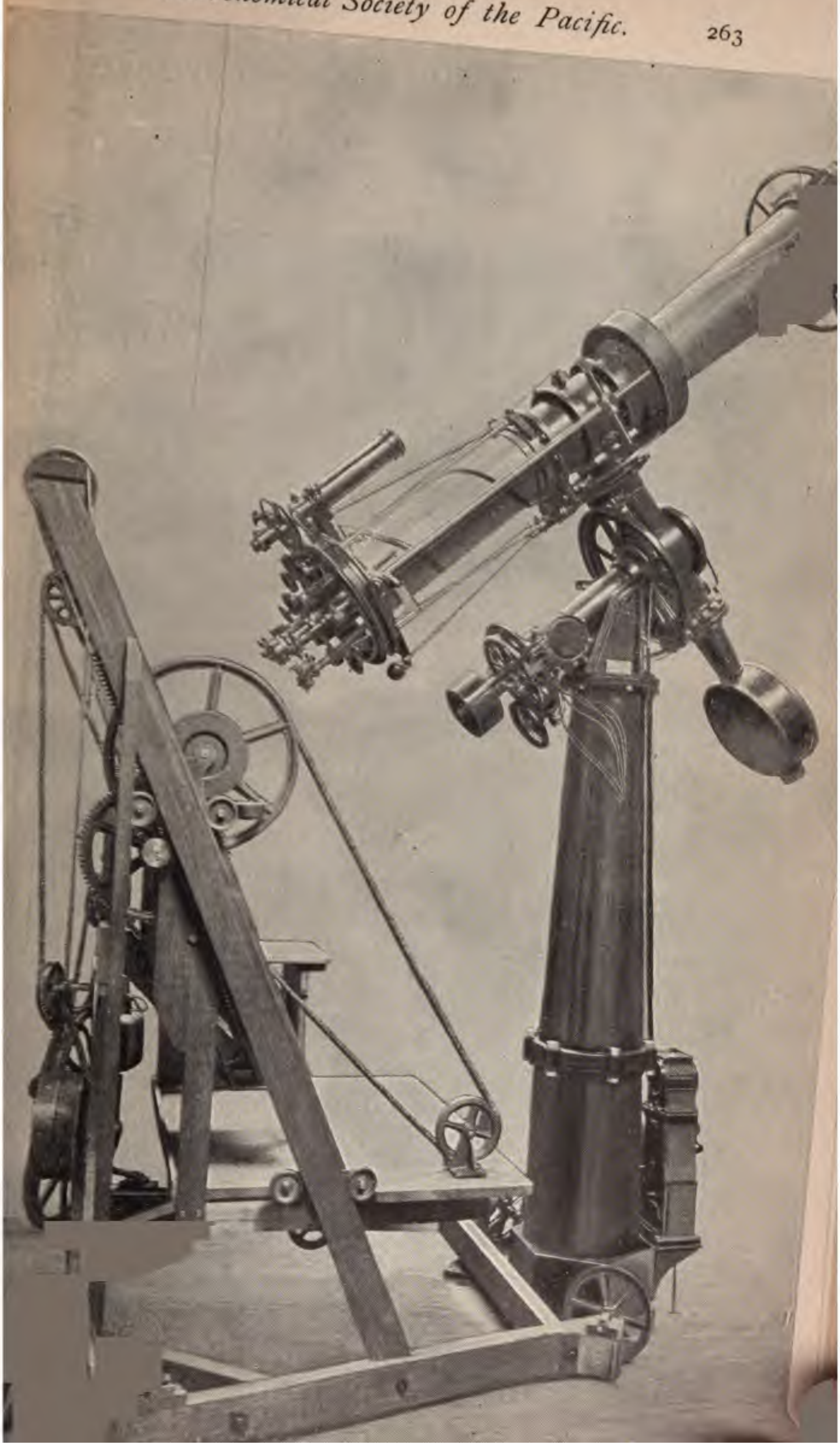


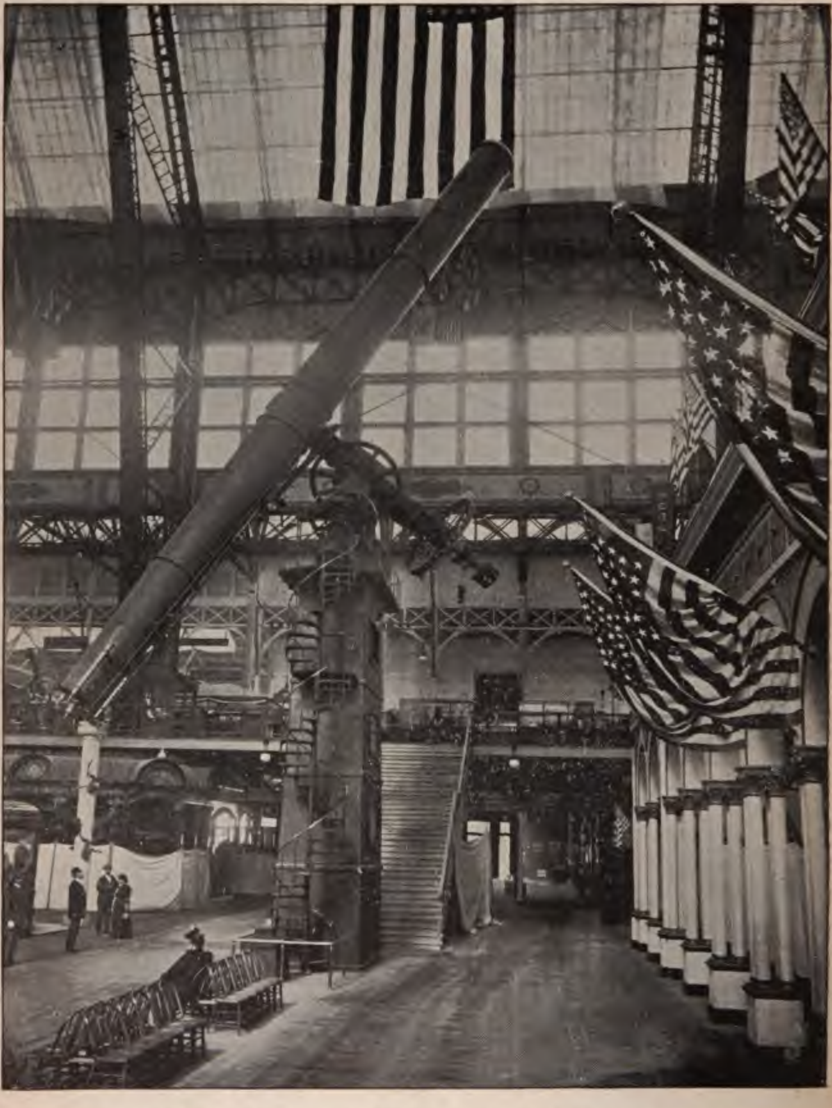
THE MERIDIAN CIRCLE, PARIS OBSERVATORY.





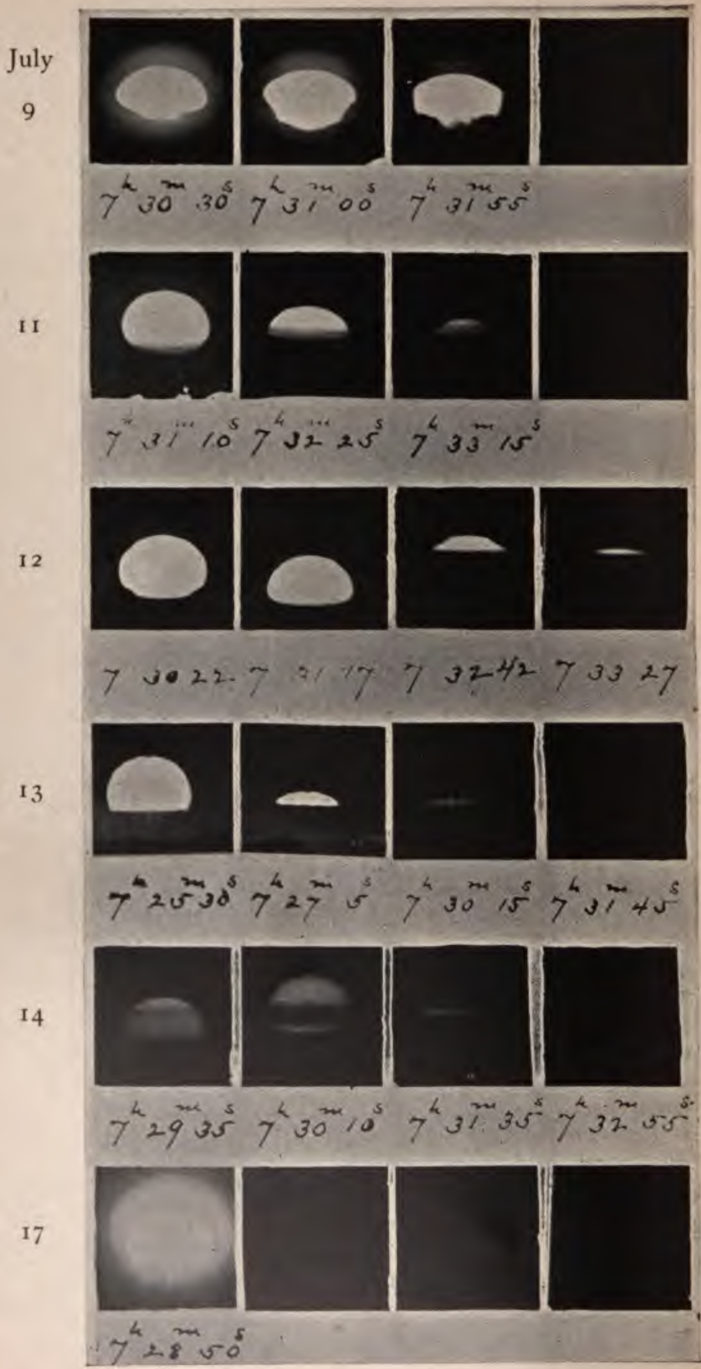
THE TWENTY-SIX-INCH REFRACTOR OF THE NATIONAL OBSERVATORY, WASHINGTON.





FORTY-INCH REFRACTOR OF THE YERKES OBSERVATORY.

1893.


July
9
$7^h 30^m 30^s$ $7^h 31^m 00^s$ $7^h 31^m 55^s$
11
$7^h 31^m 10^s$ $7^h 32^m 25^s$ $7^h 33^m 15^s$
12
7 30 22 7 31 17 7 32 42 7 33 27
13
$7^h 25^m 30^s$ $7^h 27^m 5^s$ $7^h 30^m 15^s$ $7^h 31^m 45^s$
14
$7^h 29^m 35^s$ $7^h 30^m 10^s$ $7^h 31^m 35^s$ $7^h 32^m 55^s$
17
$7^h 28^m 50^s$

SUNSETS AT MOUNT HAMILTON.

(Photographed by A. L. Colton.)

PUBLICATIONS

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"WHEN THE MOON RUNS HIGHEST AND RUNS LOWEST."

BY ROSE O'HALLORAN,
Member A. S. P.

Though subject to the unbending rule of solar and terrestrial attraction, the path of the Earth's satellite is no cast-iron groove on the highway of the heavens. Within the boundaries of a zone extending nearly six degrees on each side of the ecliptic, or Sun's path, her sway is complete; and every star in the allotted realm is, sooner or later, blotted out of view by her intervening disk. Even the Sun himself occasionally yields to this supremacy, though the glory of his corona at such a time rivals the impressiveness of the Moon's achievement.

Being but a vassal monarch, her scope has its restrictions, and, unlike the erratic comet and the lawless meteor, there are tracts in the firmament where she has never been seen, for no combination of perihelion, perigee, and planetary interference can extend her variations beyond a certain limit.

Inside her allotted zone, her range, though complete, is methodical. For instance, near that point of the celestial sphere called the vernal equinox she may glide by the tail of *Cetus*, five degrees south of it, or by the *Western Fish*, five degrees north of it; but nine years must elapse between the times that she skirts these opposite edges of her roadway.

In like manner she may occult the *Pleiades* (as she has frequently done of late), but, in the meantime, the *Hyades* will glimmer in immunity from occultation to the end of the century.

This is owing to the fact that the angle of five degrees which the plane of the Moon's orbit makes with the plane of the ecliptic reverses its position in about nine years, three and a half months; for it lacks the greater permanence of direction of the planetary angles.

In each sidereal revolution, as seen on the heavens, she passes from a point on the edge of her zone obliquely inward for about ninety degrees, when she crosses the ecliptic, and continuing obliquely, reaches a point ninety degrees farther, which is on the opposite side of the celestial sphere, and also on a different edge of her zone.

Another curve inward of about ninety degrees brings her to the ecliptic again, which is recrossed nearly opposite to the previous intersection; and, generally, *before* the revolution is fully completed, the edge has again been reached, though somewhat west of the first point.

On account of different positions with regard to Earth and Sun, and her varying distance from these orbs, these specified divisions of her orbit are far from being exact quadrants, and are not apportioned equally to the quarters of her period of twenty-seven and one-third days, but have a tendency on the whole to be completed a few hours in advance of an entire circuit in Right Ascension.

Thus these points on the bounds of the lunar zone, and also the nodes or intersections with the ecliptic, are not the same in two consecutive revolutions, but are found in the course of a year to have moved about nineteen degrees westward, or in a direction contrary to the order of the signs. This movement, known as the retrograde motion of the nodes, results in a network of pathways which, for general conception, may be thought of as one and a half degrees apart, though in reality a wavering, irregular network, frequently tangled by the varying influence of gravity.

Two hundred and forty-eight revolutions and a period of six thousand seven hundred and ninety-three and one-third days are required to complete the reticulations from border to border along the zone; and then the complex but systematic wanderings are retraced with little variation.

This periodic repetition of her routes was more or less accurately known to the sages of antiquity, who gave the name of *Saros* to the eighteen-year cycle which brought a recurrence of eclipses in nearly the same part of the heavens.

These interesting phenomena, however, are incidents of her wanderings that lie outside the scope of this paper, which is designed only to call attention to the most noticeable results of the varying declinations* attained during a sidereal cycle of eighteen years and seven months. Those who are familiar with the imaginary circles of the celestial sphere, and with the relative positions of the celestial equator, and the ecliptic, or Sun's apparent path, will readily understand the effect of a change in direction of the angle of the Moon's orbit.

As the ecliptic crosses the celestial equator at an angle of twenty-three and a half degrees, about one-half is north of that circle, the most northerly part of the curve being in *Gemini;* and the other half south of it, the most southerly course being in *Sagittarius;* while the two intersections occur, respectively, in *Virgo* and *Pisces.*

In the following diagrams, which represent the most striking differences of position, the lunar path for ninety degrees on each side of the vernal equinox is supposed to be viewed from the center of the earth, as from that ideal standpoint of observation the obstructing horizon can be dispensed with.

The arrows show the direction of the Moon's motion.

For convenience of explanation, the present cycle may be dated from June, 1885, when the path held the position represented in diagram 1. At that time the north edge touched was that north of the most southerly curve of the ecliptic, and the south edge, south of its most northerly curve.

She descended in the vernal equinox where the ecliptic crosses above the celestial equator, and, at the opposite node, ascended in *Virgo,* where the ecliptic passes down. Consequently, her range was between the two circles, and her declination varied only from eighteen degrees north to eighteen degrees south, which points corresponded respectively with her most southerly and northerly latitudes.

Diagram 2 shows the result of the gradual change during the succeeding four years and seven to eight months. In February, 1890, the ascending node had then retrograded into *Gemini,* and the descending node into *Sagittarius;* while the extremes of Declination corresponded with the ecliptic angle, and lunar latitude five degress south was in *Cetus*, south of the vernal equinox, and five degrees north in *Virgo*, north of the autumnal equinox.

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* It may be necessary to remind the reader that the positions given are those the Moon would have if viewed from the Earth's center, as is customary, to avoid the conflicting effects of parallax.

Diagram 3 represents what may be called the climax of change when the ascending node is near the vernal equinox where the ecliptic passes above the celestial equator, and the highest point is in *Auriga*, a constellation rarely invaded by the lunar disk. On September 15th of the present year the Moon, then a few hours past full, crossed the ecliptic within 1° 35′ of the vernal equinox, and ranging north and east till September 22d, attained, as seen from the center of the earth, a declination of 28° 44′ 18″ when in $6^h\ 1^m$ Right Ascension. This was the highest declination and consequently the highest altitude attained during the present cycle.

As lunar wanderings are never abrupt, she was nearly as high in the heavens twenty-seven days previous, or on August 25th, when in North Declination 28° 40′ 19″, and also during the subsequent lunation, October 19th, when in Declination 28° 40′ 51″.

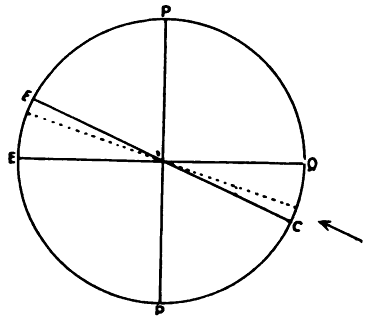
However, a few minutes of an arc are quite a measurable portion of the heavens and important in lunar distances.

The evening crescent of March 31st, 1876, visible in Europe, but obscured by sunlight to observers in America until it had been curving downward for several hours, had the highest declination of the last cycle; but as this was only 28° 43′ 29″, and consequently forty-nine seconds lower than that of September 22d, the waning half moon of that morning was farther north than our satellite had been in a period of more than thirty-seven years.

Being near the meridian of observers on the Pacific Coast, its high altitude was conspicuous and entailed altitudinal difficulties not often encountered when observing the moon in intermediate latitudes.

Before sunrise, as the silvery intruder dimmed the lights of the *Charioteer* and glanced on the California coast through a less depth of atmosphere than for many years before, a telescopic observation of its surface was taken at the choice moment of highest altitude.

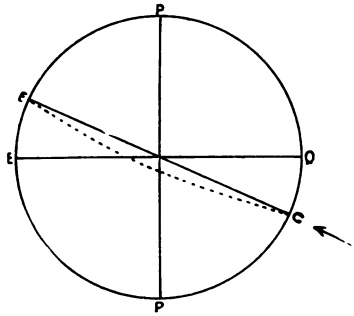
The libration in latitude, then at its maximum, revealed the rugged southern tracts far beyond *Tycho*, while the northern limb was unusually near *Plato*, and the Alpine peaks projecting into sunlight. It is to be hoped that the unique outlines and



P P, Poles. E Q, Equator. E C, Ecliptic.

DOTTED LINE, MOON'S PATH, 1885.

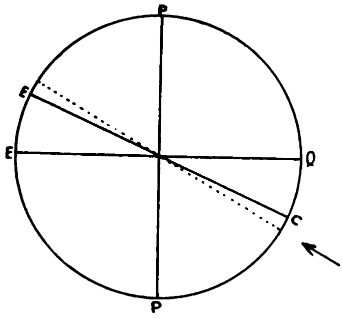
Diagram 1.



P P, Poles. E Q, Equator. E C, Ecliptic.

DOTTED LINE, MOON'S PATH, 1890.

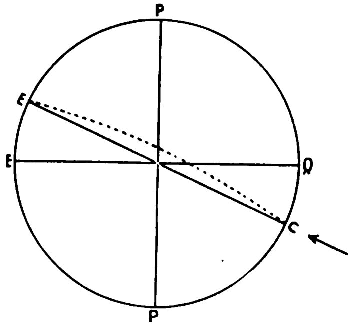
Diagram 2.



P P, Poles. E Q, Equator. E C, Ecliptic.

DOTTED LINE, MOON'S PATH, 1894.

Diagram 3.



P P, Poles. E Q, Equator. E C, Ecliptic.

DOTTED LINE, MOON'S PATH, 1904.

Diagram 4.

shadows of that hour have been preserved for future comparison by means of the camera.

As shown in Diagram 3, when the Moon's most northerly latitude corresponds with its most northerly declination, the most southerly latitude will be also attained about the same time as the most southerly declination.

Accordingly, on October 5th, less than two weeks from the date of highest altitude, the phase near first quarter when in R. A. $18^h\ 1^m\ 54^s$ had a South Declination of 28° 43′ 39″, a more southerly range than had been attained since March 17, 1876. Eight hours later it was on the meridian of Pacific Coast observers, glimmering like a gauntlet on the outstretched arm of the *Archer*, instead of forming his shield or helmet, as usual.

As the libration in latitude on this occasion revealed the north polar regions, such inconspicuous craters as *Scoresby*, *Meton*, and *Euctemon* were distinctly noticeable within the terminator which curved by the *Sea of Serenity*, skirted the complexities of *Stöffler* to the south, and joined the limb, leaving some well-known south polar summits on the other side of the moon.

As explained above, a near approach to the extremes of declination is also made in previous and subsequent lunations. The waning, gibbous Moon of September 8th and the crescent of November 1st were within nearly one minute of an arc of the same southerly position.

But the waning half moon of March 17, 1876, was forty-four seconds farther south, a declination that cannot again be equaled until the spring of 1913, and perhaps not even then.

Thus, in the present lunar cycle, the highest North Declination was attained, while in the last cycle the southward curve exceeded it by about five seconds of an arc, the difference being due to slight variations in the angle that the Moon's path makes with the ecliptic, and to a difference in Right Ascension. In 1899 the most northerly and southerly declination shall again have decreased to that of the ecliptic in *Gemini* and *Sagittarius;* but, as shown in Diagram 4, the ascending and descending nodes shall have exchanged the positions held in 1890, and the path shall curve above instead of below the vernal equinox.

In 1904, the intermediate position shown in the first diagram shall be resumed, and the cycle completed. As the extremes of declination described above were not coincident with full moon either in the past or present cycle, it will be of interest to note the highest and lowest declination of that conspicuous phase.

The lunar tables show that the full moon of December 30, 1876, when in R. A. $6^h 43^m$ had a North Declination of $27° 36' 7''$. It shone from the zenith of Egyptian lands, but was probably of equal radiance a few hours later when at perigee and on the meridian of the Southern States of North America.

But the full moon of December 22, 1893, R. A. $6^h 6^m$, was still higher, having a Declination of $28° 17' 25''$; and being only half a degree past perigee, was in a better position for light-giving on mid-Atlantic north of N. latitude 28° than at any time within thirty-seven years. This increase of light is not merely theoretic, as the apparent size of the disk increases as the square of the apparent diameter; and with a combination of high altitude and perigee seems one-fourth larger than when near the horizon and at its greatest distance.

To Pacific Coast observers it had a medium altitude north of east. When on the meridian a few hours later, and several seconds lower in declination and a few degrees past perigee, it was one of the brightest full moons of this cycle. No doubt many who chanced to look out at midnight wondered at the distinctness of the landscape.

On the seashore, where the atmosphere is apt to frustrate its illuminating powers, the decrease of distance was otherwise evinced; for its attractive forces never fail to leave their record on the surging wave. Before many hours elapsed the waters had rippled farther in than usual along the Pacific Coast from San Diego to Alaska, and according to the predictions of the tide-tables, the increased range was not fully equaled for more than a year.

At such times many rush-grown tracts, for years watered only by rain and fog, are reclaimed by the ocean under the guiding rule of the perigean Moon.

The sound of the waves are thus as truly the music of the spheres as if waked by a visible touch from ethereal heights.

The voice of an unwonted tide, whether it whispers of the Moon's approach among the rushes, or roars the tidings on the high cliffs, is the most impressive of all the voices of inanimate nature.

The recent shipping disasters were no doubt largely due to the increase of lunar influence on the atmosphere and waters beyond semi-tropical regions; for the life experience of a mariner is not sufficient to familiarize him practically with the possibilities of the eighteen-year cycle.

During a period of about three years in each cycle, the spring tides of summer, and more especially those of winter, roll in beyond their wonted bounds very noticeably, and occasionally the perigean tide, with conspiring winds and currents, brings ruin in its path.

Those who understand the causes of the two daily tides and their variations can readily call to mind the necessary effect of an increase of declination when the new or full moon is in perigee. Persons who have had continual opportunity of noticing ships in port can generally recall at least one period when the hulls were visible high above the usual level, and in some cases in the plane of the partly submerged wharf.

In the tide-tables of the year 1876 the predicted range of the winter perigean tides from higher high to lower low was one foot and three-tenths less than that of December 23, 1893, at the port of San Francisco.

Using this port as a gauge, we find from *Davidson's Coast Pilot* that the average difference between higher high and lower low in consecutive hours is five and two-tenths feet. Consequently, the predicted range on the above date being eight and one-tenth feet was nearly three feet beyond the average.

A range of two and three-tenths feet beyond the average was predicted for the twelve hours succeeding the full moon of December 12, 1894, and a range as great as three and two-tenths for January 10, 1895. The difference in the three ranges may be traced to more or less effective combinations of favorable conditions.

The learned professor, to whose official labors in the interests of navigation the public are indebted for the valuable book above named, has courteously furnished to the writer the tidal data and and further explained that the grade of the ocean-bed, the interference of currents and winds, and the influences of climate are important factors in tidal effects, and sometimes create a difference between the table of predictions and the observed range.

The full moons that hung low down in the midnight summer skies were not such effective tide-raisers during either cycle as the same phases in winter, but their characteristics were equally distinct.

In northern countries they rose in the southeast late in the evening, and seemingly of unwonted size, shone for a few hours in picturesque proximity to the southern landscape, a striking verification of the law that "in summer, when the Sun runs highest, the full moon runs lowest."

The beautiful orb of June 17, 1894, was somewhat lower than the most southerly Moon of 1876.

When the occultation of stars is considered, even a few seconds of an arc are an important difference. The starry pathway being slightly different in successive revolutions, the various occultations are a conspicuous and interesting effect of lunar wanderings.

From time to time each of the major planets is cut off from view by the roving satellite of the Earth, but *Mercury* alone is ever encountered in the extremes of lunar latitude or Declination. *Aldebaran*, *Regulus*, *Antares*, *Spica*, the only stars of first magnitude within five degrees of the ecliptic, are generally occulted during each cycle to observers in some part of the Earth, for, on account of parallax, occultations depend on the latitude and longitude of observers. When, at long intervals, it is found that such stars as 49 and 54 *Auriga* and *e* and *Gamma Sagittarius* have been occulted, perhaps, a few times in succession, it is evidence that the queenly orb has speeded around the most northerly and southerly confines of her sidereal realm.

Like milestones the stellar lights mark her progress along the winding interlacing journey of years' duration which ends only to be re-commenced again and again for endless ages.

SAN FRANCISCO, CAL.

PLANETARY PHENOMENA FOR NOVEMBER AND DECEMBER, 1895.

By PROFESSOR MALCOLM MCNEILL.

NOVEMBER.

Occultations. The Moon passes over the *Pleiades* twice, on November 3d in the early evening, and again on the night of November 30th, or rather, early in the morning on December 1st. On November 3d the Moon is just past full and the immersions will be at the bright limb and the emersions at the dark limb. The occultations at the end of the month occur just before the Moon is full, and the immersions will be at the dark limb. The exact times of the occultations depend so much on the position of the observer that there is no use in giving them for any particular place, as they would be nearly useless for any other. At each series a number of the brighter stars will be occulted, and it is a phenomenon well worth observing for all who have telecopes of even small size.

The planets are for the most part best seen before sunrise in the morning, but most of them are too near the Sun to be very conspicuous.

Mercury is a morning star throughout the month, and reaches its greatest elongation on November 10th. It then rises about an hour and forty minutes before sunrise, and will be an easy object for naked-eye observation under good weather conditions. Except during the last few days of the month, it rises at least an hour earlier than the Sun. It moves rapidly eastward among the stars, and toward the close of the month comes into conjunction with *Saturn*, *Mars*, and *Uranus*, the closest being that with *Saturn* on November 20th. On the morning of that day, *Mercury* will be south of *Saturn* only a little more than the Moon's diameter. They approach still closer after sunrise in the United States.

Venus is the most brilliant in the morning sky, and reaches its greatest west elongation on November 29th, when it rises about four hours before the Sun. At the close of the month it is not far from the first magnitude star *Spica (Alpha Virginis)*.

Mars passed conjunction with the Sun on October 11th, and is now a morning star, but cannot be easily seen, on account of its faintness and nearness to the Sun. At the end of November it rises nearly an hour and a half before the Sun, and a sharp eye may detect it in the morning twilight, if the air is very clear. On November 18th it passes only six minutes south of the third magnitude star *Alpha Libræ*.

Jupiter is getting around again to good position for those observers who do not care to sit up all night. By the end of the month it rises at about 9 P. M. It is in the constellation *Cancer*, and moves eastward about one degree from November 1st to November 25th, and then it begins to retrograde. It is a little south and east of "Præsepe," the "Bee-hive" cluster, in *Cancer*.

Saturn is in conjunction with the Sun on November 2d. By the end of the month it rises about two hours earlier, but it will not be at all conspicuous. It is in conjunction with *Mars* on

November 16th, when both are too near the Sun to be easily seen, and with *Mercury* on November 20th; at this time the conditions for visibility are a little better.

Uranus is in conjunction with the Sun on November 12th, and does not get far enough away to be seen.

Neptune is in the eastern part of the constellation *Taurus*.

DECEMBER.

The Sun reaches its greatest Southern Declination, and winter begins, at 5 P.M., December 21st, P. S. T.

Mercury is a morning star at the beginning of the month, rising not quite an hour before sunrise. It will be scarcely possible to see it, unless under exceptionally favorable weather conditions. It rapidly approaches the Sun and passes superior conjunction on December 20th, becoming an evening star.

Venus is still a morning star, and throughout the month keeps about the same distance away from the Sun, moving eastward among the stars at about the same rate as the Sun. It moves through the constellation *Virgo* from a position near *Alpha Virginis*, and through *Libra*, nearly reaching *Scorpio* by the end of the month.

Mars keeps its position relative to the Sun nearly unchanged, rising about an hour and a half to two hours before sunrise. On the morning of December 15th it passes about one degree south of the third magnitude star *Beta Scorpii*. It will be somewhat brighter than the star, about one magnitude, but it has not begun to brighten up very much yet.

Jupiter is beginning to get into comfortable position for evening observation; by the end of the month it rises before 7 P.M. During the month it retrogrades (moves westward) about two degrees in the constellation *Cancer*. It moves toward the fourth magnitude star *Delta Cancri*, and at the end of the month passes to the south of the star at a distance about equal to the Moon's diameter.

Saturn is a morning star somewhat farther away from the Sun than it was during November. At the end of December it rises about four hours before sunrise. During the month it moves about three degrees eastward from a position about two degrees north of the third magnitude star *Alpha Libræ*. It is in conjunction with *Venus* on December 22d, *Venus* passing to the south of *Saturn* at a distance about equal to the Moon's diameter.

The minor axis of the rings is apparently a little greater than it was before conjunction, owing to the movement of the earth with reference to their plane.

Uranus is also a morning star, nearer the Sun than *Saturn* is, and is too low for naked-eye observation. It is moving eastward, and is several degrees east of its position during the summer.

Neptune is in the eastern part of the constellation *Taurus*. It is in opposition on December 8th.

EXPLANATION OF THE TABLES.

The phases of the Moon are given in Pacific Standard time. In the tables for Sun and planets, the second and third columns give the Right Ascension and Declination for Greenwich noon. The fifth column gives the local mean time for transit over the Greenwich meridian. To find the local mean time of transit for any other meridian, the time given in the table must be corrected by adding or subtracting the change per day, multiplied by the fraction whose numerator is the longitude from Greenwich in hours, and whose denominator is 24. This correction is seldom much more than 1^m. To find the standard time for the phenomenon, correct the local mean time by *adding* the difference between standard and local time if the place is west of the standard meridian, and *subtracting* if east. The same rules apply to the fourth and sixth columns, which give the local mean times of rising and setting for the meridian of Greenwich. They are roughly computed for Lat. 40°, with the noon Declination and time of meridian transit, and are intended as only a rough guide. They may be in error by a minute or two for the given latitude, and for latitudes differing much from 40° they may be several minutes out.

PHASES OF THE MOON, P. S. T.

		H. M.
Full Moon,	Nov. 2,	7 18 A. M.
Last Quarter,	Nov. 9,	3 6 P. M.
New Moon,	Nov. 16,	9 11 A. M.
First Quarter,	Nov. 23,	11 19 P. M.

THE SUN.

1895.	R. A. H. M.	Declination. ° ′	Rises. H. M.	Transits. H. M.	Sets. H. M.
Nov. 1.	14 26	−14 27	6 31 A.M.	11 44 A.M.	4 57 P.M.
11.	15 6	−17 27	6 42	11 44	4 46
21.	15 47	−19 56	6 54	11 46	4 38
Dec. 1.	16 30	−21 50	7 5	11 49	4 33

MERCURY.

Nov. 1.	13 38	− 8 52	5 23 A.M.	10 56 A.M.	4 29 P.M.
11.	13 54	− 9 16	5 2	10 33	4 4
21.	14 45	−14 14	5 30	10 44	3 58
Dec. 1.	15 46	−19 21	6 10	11 5	4 0

VENUS.

Nov. 1.	11 44	+0 42	2 57 A.M.	9 2 A.M.	3 7 P.M.
11.	12 14	−1 1	2 53	8 52	2 51
21.	12 48	−3 35	2 56	8 47	2 38
Dec. 1.	13 26	−6 41	3 6	8 46	2 26

MARS.

Nov. 1.	14 0	−11 46	5 55 A.M.	11 18 A.M.	4 41 P.M.
11.	14 26	−14 7	5 50	11 4	4 18
21.	14 53	−16 18	5 46	10 52	3 58
Dec. 1.	15 21	−18 17	5 40	10 40	3 40

JUPITER.

Nov. 1.	8 43	+18 38	10 52 P.M.	6 2 A.M.	1 12 P.M.
11.	8 45	+18 30	10 16	5 25	12 34
21.	8 47	+18 27	9 39	4 47	11 55 A.M.
Dec. 1.	8 47	+18 29	8 59	4 8	11 17

SATURN.

Nov. 1.	14 33	−12 44	6 31 A.M.	11 51 A.M.	5 11 P.M.
11.	14 37	−13 6	5 57	11 16	4 35
21.	14 42	−13 27	5 24	10 41	3 58
Dec. 1.	14 46	−13 48	4 50	10 6	3 22

URANUS.

1895.	R. A. H. M.	Declination. ° ′	Rises. H. M.	Transits. H. M.	Sets. H. M.
Nov. 1.	15 9	− 17 20	7 24 A.M.	12 26 P.M.	5 28 P.M.
11.	15 11	− 17 31	6 48	11 50 A.M.	4 52
21.	15 14	− 17 41	6 12	11 13	4 14
Dec. 1.	15 16	− 17 51	5 35	10 36	3 37

NEPTUNE.

Nov. 1.	5 7	+ 21 24	7 6 P.M.	2 26 A.M.	9 46 A.M.
11.	5 6	+ 21 23	6 26	1 46	9 6
21.	5 5	+ 21 21	5 46	1 6	8 26
Dec. 1.	5 4	+ 21 19	5 5	12 25	7 45

PHASES OF THE MOON, P. S. T.

		H. M.
Full Moon,	Dec. 1,	10 38 P. M.
Last Quarter,	Dec. 8,	11 9 P. M.
New Moon,	Dec. 15,	10 30 P. M.
First Quarter,	Dec. 23,	9 21 P. M.
Full Moon,	Dec. 31,	12 31 P. M.

THE SUN.

1895.	R. A. H. M.	Declination. ° ′	Rises. H. M.	Transits. H. M.	Sets. H. M.
Dec. 1.	16 30	− 21 50	7 5 A.M.	11 49 A.M.	4 33 P.M.
11.	17 13	− 23 1	7 13	11 53	4 33
21.	17 57	− 23 27	7 20	11 58	4 36
31.	18 42	− 23 6	7 23	12 3 P.M.	4 43

MERCURY.

Dec. 1.	15 46	− 19 21	6 10 A.M.	11 5 A.M.	4 0 P.M.
11.	16 51	− 23 8	6 51	11 31	4 11
21.	17 59	− 25 0	7 28	12 0	4 32
31.	19 10	− 24 34	7 58	12 32 P.M.	5 6

VENUS.

Dec. 1.	13 26	− 6 41	3 6 A.M.	8 46 A.M.	2 26 P.M.
11.	14 6	− 10 4	3 18	8 47	2 16
21.	14 49	− 13 26	3 33	8 50	2 7
31.	15 35	− 16 32	3 51	8 56	2 1

MARS.

1895.	R. A. H. M.	Declination. ° ′	Rises. H. M.	Transits. H. M.	Sets. H. M.
Dec. 1.	15 21	− 18 17	5 40 A.M.	10 40 A.M.	3 40 P.M.
11.	15 49	− 20 2	5 38	10 30	3 22
21.	16 19	− 21 29	5 34	10 20	3 6
31.	16 49	− 22 38	5 29	10 11	2 53

JUPITER.

Dec. 1.	8 47	+ 18 29	8 59 P.M.	4 8 A.M.	11 17 A.M.
11.	8 45	+ 18 37	8 17	3 27	10 37
21.	8 43	+ 18 49	7 35	2 45	9 55
31.	8 39	+ 19 6	6 51	2 2	9 13

SATURN.

Dec. 1.	14 46	− 13 48	4 50 A.M.	10 6 A.M.	3 22 P.M.
11.	14 51	− 14 6	4 16	9 31	2 46
21.	14 55	− 14 23	3 43	8 56	2 9
31.	14 58	− 14 38	3 8	8 20	1 32

URANUS.

Dec. 1.	15 16	− 17 51	5 35 A.M.	10 36 A.M.	3 37 P.M.
11.	15 18	− 18 0	4 59	9 59	2 59
21.	15 21	− 18 8	4 23	9 22	2 21
31.	15 23	− 18 16	3 46	8 45	1 44

NEPTUNE.

Dec. 1.	5 4	+ 21 19	5 5 P.M.	12 25 A.M.	7 45 A.M.
11.	5 2	+ 21 18	4 21	11 40 P.M.	6 59
21.	5 1	+ 21 16	3 40	11 0	6 20
31.	5 0	+ 21 15	3 0	10 20	5 40

FOUCAULT'S PENDULUM EXPERIMENT.

By Torvald Köhl.

On the 17th and 20th of July I made a repetition of Foucault's pendulum experiment in the Cathedral of Roskilde, near Copenhagen, the mausoleum for the kings of Denmark. The pendulum had a length of twenty-two metres and a weight of thirty-five kilogrammes, the cylinder being of lead; the steel wire was eight-tenths of a millimeter thick.

The point of the pendulum passed through two layers of dry sand, placed on opposite sides of a circle, which was of such a size that every degree of the circumference was exactly one inch in length. The calculated deviation of one degree in each five minutes was exactly observed during more than an hour and by that time the audience had become fully convinced as to the daily motion of our restless globe.

Odder, Denmark, August 3, 1895.

NOTE ON A CAUSE OF DIFFERENCES BETWEEN DRAWINGS AND PHOTOGRAPHS OF NEBULÆ.

By James E. Keeler.

A comparison of the best drawings and photographs of nebulæ reveals at once the existence of considerable discrepancies between the forms depicted by methods so widely different. In support of this statement it is sufficient to quote the words of Dr. Roberts, who says, in briefly summing up the results of such a comparison: "All drawings alike fail to present to the eye proportions, details, and outlines as they are shown on the photographs."*

These discrepancies must no doubt be ascribed largely to the difficulty of the draftsman's task, and to certain well-recognized peculiarities of photographic action affecting the density of the silver deposit on a sensitive plate. It is found, however, that

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Mon. Not. R. A. S., Vol. XLIX, page 390, (1889).

regions of equal brightness are not similarly placed on both drawings and photographs, and differences of this kind are less readily accounted for than differences of form. Now, recent researches on the spectra of the nebulæ have shown that, in at least the case of the *Orion* nebula, drawings and photographs *must* differ, for a reason which has no relation whatever to the draftsman's skill. It is more or less distinctly recognized in various papers relating to the photography of nebulæ, and is probably known to all who have followed the progress of astronomical spectroscopy, but it may not have occurred to others, and I have thought that it would be worth while to emphasize its importance in a special note.

The spectrum of the *Orion* nebula (which it will be sufficient to consider at present) consists of the two chief nebular lines λ5007 and λ4959, the lines of the hydrogen series, the ultra-violet line λ3727, and a number of faint lines which need not be specially mentioned. If we compare the visual and actinic effects of these different lines, we find that a photograph on an ordinary dry-plate is practically a record of the distribution of hydrogen in the nebula, though it is modified to some extent by light emanating from unknown substances.* The image seen in the telescope, on the other hand, corresponds nearly to the distribution of the substance (or substances) yielding the two principal nebular lines, although in this case also the impression is a composite one, as the Hβ line of hydrogen is fairly bright. Roughly speaking, however, the photographic and visual images are due to light coming from different substances, and they will not agree unless these substances are distributed in the same manner in space.

Now, according to Professor CAMPBELL,† whose results I have been able to partially confirm with my inferior means, the relative intensities of the principal line and the Hβ line in the spectrum of the *Orion* nebula vary enormously; namely, from about 4:1 to about 4:20 for different parts of the nebula. We may safely take the brightness of the Hβ line as a measure of the strength of the whole hydrogen series, and as the intensity-ratio of the two principal lines in the visual spectrum is constant,* we have in these observed facts a sufficient explanation of the differences between drawings and photographs, which form the subject of the present note.

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* According to my own photographic observations, the intensities of the lines in the Huyghenian region are related about as follows: hydrogen series, 51; (γ3727), 7; other lines, 10.—*Astronomy and Astro-Physics*, June, 1894.

† *Publications* A. S. P., No. 32, page 206.

The regions in which the Hβ line is relatively bright are, according to Professor CAMPBELL,† the fainter parts of the nebula remote from the trapezium. These regions should therefore be relatively strong on the photographs, as they are in fact.

It is interesting to note that the non-homogeneous constitution of the *Orion* nebula was suspected by Dr. HENRY DRAPER,‡ on the strength of a photograph of the spectrum taken by him in March, 1882, shortly before his death. On this photograph the ratio of intensity of the hydrogen lines Hγ and Hδ to that of two faint lines in the same region (probably λ4026 and λ4069) was not constant at all points. Had he lived, Dr. DRAPER would doubtless have investigated this subject more completely. With reference to DRAPER's photograph of the nebula made at about the same time, Professor HOLDEN remarks in his *Monograph* that it represents the result of eye-observations more nearly than ordinary (wet) plates would do, since the plates used by Dr. DRAPER were sensitive to rays lower in the spectrum than *b*. The conclusion would be correct, if the premises were, but in the light of our present knowledge, this does not seem to be the case. DRAPER used gelatino-bromide plates, which are not sensitive below Hβ without forced exposure, and on his photographs of the spectrum (presumably) taken with the same plates, even the Hβ line did not appear.

Professor W. H. PICKERING has recently studied the constitution of the *Orion* nebula by photographing the nebula with an objective prism. § Each line in the spectrum gives a monochromatic image of the nebula. Partly on account of the overlapping of these images, and partly on account of the numerous strong star-spectra superposed on them, the results (judging by the reproduction in plate II) are somewhat less satisfactory than the beauty of the method might lead one to expect. As the lowest image in this photograph is that corresponding to the Hβ line, a direct comparison with the visual image is not possible, although

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* *Publications* LICK Observatory, Vol. III, page 228.

† *Publications* A. S. P., No. 32, page 206.

‡ *American Journal of Science*, Vol. XXIII, page 340.

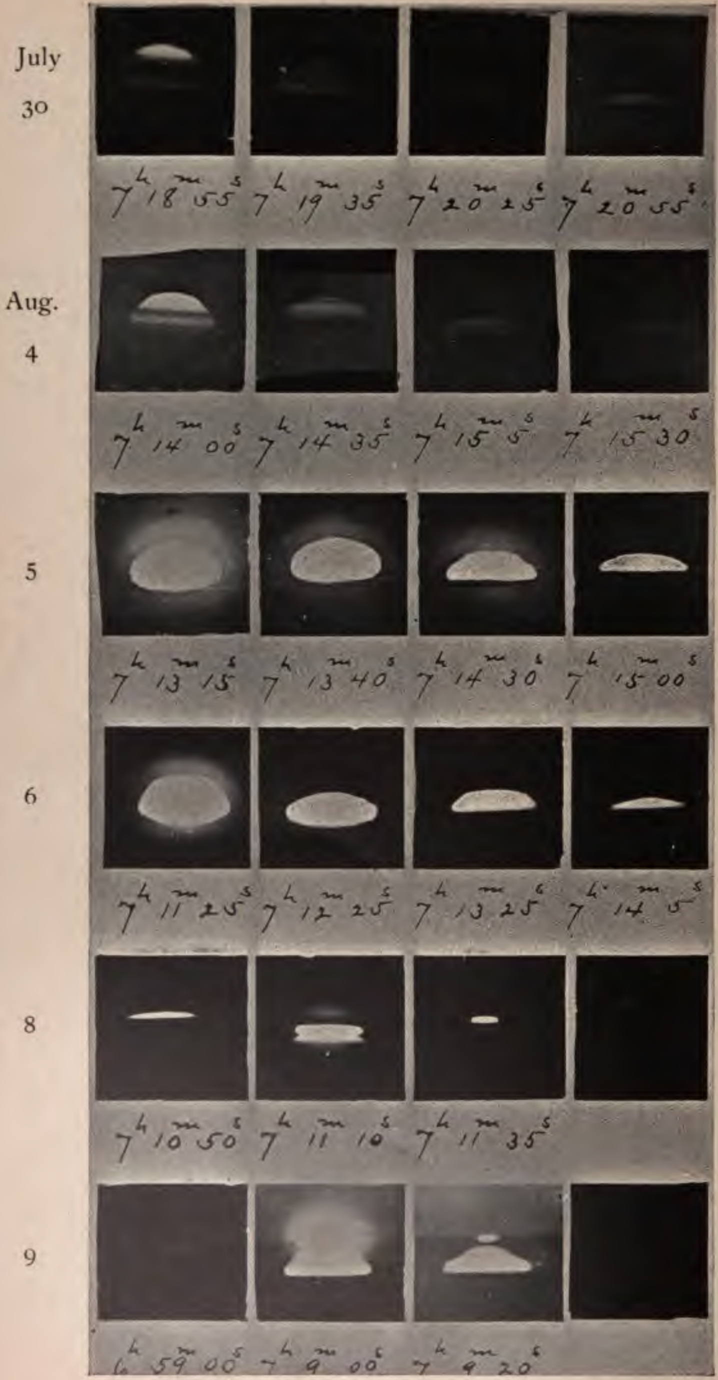
§ *Annals H. C. O.*, vol. 32, Part I.

Professor PICKERING points out that the great strength of the λ 3727 image in certain parts of the Huyghenian region accounts for the relatively greater brightness of these parts on an ordinary photograph of the nebula. The same method was tried by DRAPER, but with the greatly inferior arrangement of a direct-vision prism placed near the focus of the telescope.

It seems to me that an easy and satisfactory method of studying the distribution of matter in the nebula would be to photograph the nebula with an ordinary refractor (or, still better, with a reflector), with a fairly good piece of green or yellowish green glass in front of an orthochromatic plate. The glass, which should absorb practically all the light except that of the two principal nebular lines, could be tested by photographing the spectrum through it with a slit spectroscope. A photograph obtained by the above method would be directly comparable with drawings, and in case a reflector were used, it could be compared with a photograph of precisely the same dimensions taken on an ordinary plate. The exposure would be much longer than that generally required, but, according to my experience in photographing the spectrum on orthochromatic plates, it would not be excessively great. Probably the whole region covered by drawings could be obtained with such exposures as have already been given to this nebula for other purposes.

Since the curve of color sensitiveness is not the same, even for different kinds of ordinary dry plates, it follows that photographs of any non-homogeneous nebula on different plates are not strictly comparable. If plates differed greatly in this respect, it would be necessary to exercise considerable caution in comparing photographs of nebulæ for evidence of change; but, since they do not differ greatly, and since the hydrogen series is fairly well distributed over the whole range of the upper spectrum, differences in photographs owing to this cause are not likely to be appreciable.

1893.



SUNSETS AT MOUNT HAMILTON.

(Photographed by A. L. COLTON.)

NOTICES FROM THE LICK OBSERVATORY.

PREPARED BY MEMBERS OF THE STAFF.

STRUCTURE OF THE MILKY WAY.

Mr. C. EASTON has lately made a comparison between different counts of stars in a portion of the Milky Way, according to a general method suggested in the *Publications* of the Washburn Observatory, Volume II, 1883, and some account of his results are given in *Knowledge* for August 1, 1895.

Mr. EASTON states his conclusions as follows: "In short, the conclusion most forcibly presented to us is that it becomes extremely probable that the great majority of the fainter stars of the Milky Way are not much more distant from us than the stars of the ninth and tenth magnitudes, at least in the regions to which our researches have extended. The Galactic system must thus have but little depth in proportion to its diameter."

The general conclusion last stated has been reached by all recent investigators, and was first insisted on by the late Mr. PROCTOR. New data bearing on the question will soon be available in the numerous photographic maps made and making at so many observatories. E. S. H.

CATALOGUE OF STARS WANTED IN THE LIBRARY OF THE LICK OBSERVATORY.

The collection of star catalogues in the library of the LICK Observatory is practically complete, with the exception of ARGELANDER'S Northern Zones. We shall be much obliged to any correspondent who will put us in the way of acquiring a copy of this work. E. S. H.

ARRIVAL OF THE CROSSLEY REFLECTOR AND DOME AT MOUNT HAMILTON.

The mirrors and finer mechanical parts of the Crossley Reflector (3200 lbs.) left Liverpool on June 28th and were delivered at Mount Hamilton by the WELLS, FARGO Express Co. on July 18th.

The mounting of the telescope (15,105 lbs.) left Liverpool June 18th, also, and was delivered at Mount Hamilton by the Southern Pacific Co. August 4th. The largest part of the Dome (47,033 lbs.) left Liverpool on July 26th and arrived at Mount Hamilton September 19th. A further shipment of twelve iron girders of the dome arrived in New York, August 15th, and arrived here September 19th.

It is probable that the erection of the iron dome will be postponed till the Spring of 1896. E. S. H.

NEW OBSERVATORIES.

The University of Pennsylvania, the Ohio State University, the CASE School of Applied Science (Cleveland), and the University of Minnesota are having telescopes built.

The observatory of the University of Pennsylvania is to be located at "Flower Farm," on the West Chester road, a short distance from Philadelphia. The ground has been broken "for the first of the new buildings to be erected there, at a cost of $50,000, and the work will be pushed rapidly to completion. It is proposed to make the building as low as possible compatible with architectural effect, to avoid giving undue height to the pier which will carry the telescope." The principal instrument of this observatory is to be an eighteen-inch refractor, with an objective by BRASHEAR.

The EMERSON MCMILLIN Observatory of the Ohio State University is to have a twelve-inch refractor, with objective and spectroscope by BRASHEAR and mounting by WARNER & SWASEY, transit by SAEGMULLER, clock by RIEFLER, and some smaller instruments.

The new telescope of the CASE School will be eleven inches aperture, and that of the University of Minnesota ten and one-half inches. The latter will be provided with a photographic corrector.

Mr. BRASHEAR is also making *two* important astro-photographic *doublets* for the University of Heidelberg, Germany. They are each to be forty centimetres (sixteen inches) clear aperture, and, on account of their large size, we may justly expect them to make an important advance in astronomical photography. Most of the doublets now in use by astronomers are from six to eight inches in aperture, and of comparatively short focal length. The Willard lens of the LICK Observatory, with which so many fine photographs of nebulæ, comets, and the Milky Way have been obtained, is only six inches in diameter and 30.82 inches equivalent focal length. The lenses which Dr. MAX WOLF has been using at Heidelberg are of the same order of magnitude. Dr. WOLF is to be congratulated on his new instruments.

W. J. H.

PHOTOGRAPHS OF THE SETTING SUN.

The two plates representing the distorted disc of the setting sun as observed at Mount Hamilton are selected from a series of ten plates, representing the sunsets on sixty different nights in the summer of 1893. The photographs were taken by Mr. A. L. COLTON, as a record of some of the curious effects of atmospheric refraction. A lens of forty-nine inches focus was used, and the original size of the images has been retained. Much of the detail of the original negatives has been lost in the reproduction. The entire series of plates, with a descriptive article by Mr. COLTON, will be included in a forthcoming volume of "Contributions from the LICK Observatory."

A VISIT TO THE OBSERVATORY OF PULKOWA — IMPRESSIONS OF A LITERARY MAN.

[From a Paper by the Vicomte EUGÈNE MELCHIOR DE VOGÜÉ.]

" * * * A troïka ride is the favorite amusement of St. Petersburg society of winter nights, and the one that leaves in the mind of the foreigner the most vivid and novel souvenir. The inns where the Tsiganes sing are the usual object of these nocturnal excursions; sometimes, however, others are suggested; for instance, to the Observatory of Pulkowa, which rises midway between Petersburg and Tsarskoe-Selo, on a hill crowned with pine trees. It is the only elevation on the marshy plains which surround the capital. There lives a little German colony; for they are Germans who keep watch over the Russian heavens.

With a few exceptions, this family of astronomers is recruited in the university at Dorpat, and holds its celestial fief with jealous care. When you enter Pulkowa, you find yourself transported to another world. You might imagine yourself in some calm institute in Goettingen or Jena. Confined in the mysteries of space and time, these modest *savants* work under the direction of their senior member or *doyen*. They live in common a patriarchal life—an honest German life, staid and serious, like that of the stars. Strangers to the noises of the great city and to the interests and passions which surround them, these astronomers have fixed the boundaries of their earthly horizon at the wood of pine trees and the roofs which shelter their households and their books. The only revolutions that they look forward to are those of the firmament; their newspapers are the tables of the Sun and planets; their subject of conversation the theorems of KEPLER, or the excellent recipe of Madame la DOYENNE for smoking the breasts of geese — an artless mixture of humble domestic cares and of the great secrets of the universe. The monks of science mount into their glass palace, wrapped up in warm cloaks, with fur caps on their heads, like the astrologers you see depicted in ancient engravings. The old *savants* conduct their pupils to the top of the tower, into that vast rotunda which revolves upon itself and seems like the poop of a ship, with its masts, its rigging, its instruments of polished brass, and its portholes where the telescopes are pointed. The lamps burn over the books, the compass moves over the charts, the telescope scrutinizes the polar regions, and the calculations of ages are continued. The observers are adding a page to the annals of the sky. At that hour, when everything which makes noise and illusion on the earth is silent, these modest people are truly the masters of the universe. They ordain its destinies; they know from whence it comes, whither it goes, and what it weighs. Grave, and proud of their responsibility, — like their brothers, the sailors,— they watch for us all. They mark the passage of the planet in the unknown, in the midst of the formidable fleets which it crosses in its passage. If some benighted traveler passes in these solitudes, he perceives up there the lights of the crew maneuvering its ærial dome; he wonders if it is not some phantom ship lost on the sea of snow, or else he may imagine that he hears monks assembled in their oratory for matins, who sing by night the praises of the Lord.

But this solitude and this peace are exposed to frequent invasions. If an eclipse is announced, the ladies of Petersburg form a party to go to Pulkowa; they either belong to the Court, or have taken the precaution to have some dignitary in their party; and consequently the Imperial Observatory could not refuse to satisfy their caprices. The troïkas deposit in the temple of science the noisy visitors, who take possession of the telescopes, and demand for their particular use that corner of the heavens where something important is about to happen. The have all these mysteries explained to them; they ferret about in albums of lunar photographs, and their curiosity is excited by the marvels that the old sorcerers tell them. The evening ends with supper of ham and sauerkraut prepared by Madame la DOYENNE, and in listening to one of the young German women play on the piano a sonata of SCHUMANN or WEBER. The joyous band then starts back, enchanted with the contrast between its habits of luxury and the austere simplicity of which it has just taken a glimpse."—*Harpers' Magazine*, Volume 78 (1889), page 851.

THE LUNAR ECLIPSE OF SEPTEMBER 3, 1895.

The observations of this eclipse made by me were almost entirely photographic. The instrument used was a twelve-inch silver on glass reflecting telescope of about forty-five inches focus, carried by the equatorial mounting made for the eighteen-inch reflector already described in a former number of these *Publications*, but recently altered somewhat to overcome, in a measure, the disturbing effects of the wind; the wooden tube has been replaced by three trussed iron pipes, which carry the large mirror at the lower end, and the secondary mirror near the upper end of the now skeleton tube.

As these photographs are the first that have ever been made with the twelve-inch mirror, the results are to be considered as of an experimental character. In all, some twenty-five negatives of the partial and total phases were obtained. CARBUTT'S lantern-slide slow plates (3¼ x 4¼) were used for the partial phase. All these negatives show that the exposure times (in the neighborhood of 4^s) were much too long. Probably $0^s.5$ to $1^s.0$ would have been about right.

For the total phase, SEED plates No. 27 were used. From data given by the WILLARD lens at previous eclipses, an exposure of from 4^m to 8^m was deemed necessary. I gave exposures varying from $1^m\ 30^s$ to 12^m, but even the shortest-timed negative shows that the plate was over-exposed. For the longer exposures the drift of the image in Declination caused easily visible distortions of the outline in Declination, as I had arranged no means of guiding for the twelve-inch.

Although the clock was regulated to the lunar rate of Right Ascension, thereby causing a drift of the star images, nevertheless more than one hundred star-trails can be counted within one degree of the Moon's outline.

The refraction effects of our atmosphere, and the unequal reflecting powers of lunar areas are strongly shown in some of the photographs of the crescent phase. Aside from the unequal distribution of the light during the total phase, the lunar surface features, illumined only by light passing through our atmosphere, appear much the same as those obtained of the full Moon.

The plates were placed in the principal focus; the diameter of the Moon's image being about 0.40 inches.

J. M. SCHAEBERLE.

LICK OBSERVATORY,
September 10, 1895.

TOTAL ECLIPSE OF THE MOON, SEPTEMBER 3, 1895.

This was a particularly bright eclipse, the disc of the Moon during totality being in general a bright red. There was a cinnamon-brown color in parts of the disc before contact with the shadow, due to emersion in the penumbra. The shadow itself appeared of tints ranging from steel-gray to olive-green, possibly the effect of contrast.

The rim of the Moon's disc could always be seen through the shadow, by the use of a strong pair of field-glasses; with which the following phases were observed:

$$\begin{array}{rl} \text{Contact with shadow,} & 8^h\ 0^m\ 20^s\ \text{P. S. T.} \\ \text{Total eclipse,} & \left\{\begin{array}{l} 9^h\ 6^m\ 50^s \\ 10^h\ 47^m\ 20^s \end{array}\right. \\ \text{Contact with shadow,} & 11^h\ 55^m\ 6^s \end{array}$$

These phenomena appear to have been observed in general about half a minute later than the ephemeris times.

An occultation of a ninth magnitude star was observed with the four-inch finder of the thirty-six-inch telescope at the east edge of the Moon, at $9^h\ 57^m\ 58^s.3$ P. S. T. The star was BD. —8°, 5996 (8.7 mag.).

During the middle of totality the disc of the Moon was nearly covered by a dark patch of shadow, extending from the N. E. to the S. W. edges; leaving narrow crescents of much brighter illumination at the S. E. and N.W. edges. R. H. TUCKER.

THE TOTAL ECLIPSE OF THE MOON, 1895, SEPTEMBER 3.

The following observations were made with the 12-inch equatorial, using a power of about 85.

The aperture was reduced to eight inches until totality began, after which the full aperture was used. The finder was used principally in observing the transit of the shadow across the disc.

There was a layer of smoke and haze near the horizon, but it did not extend very high. The top of this layer was not above our altitude, so that the sky overhead was clear, and the air very transparent.

The centre of the Earth's shadow was a very deep, but clear, pure copper color. This color became several shades lighter towards the outer edge of the shadow, where it mixed with the yellow, becoming a strong orange, and slightly green at the edge.

This eclipse was a darker one than that of March this year, although the Moon remained plainly visible all through the total phase, the main features being discernible with the naked eye, and distinct in the telescope. The Milky Way showed quite conspicuously during totality.

$7^h\ 30^m$ P. S. T.	Seeing poor; Moon low; some obscuration on S. E. limb.
$7^h\ 50^m$	The eastern limb has grown darker.
$7^h\ 58^m\ 00^s$	First contact with shadow.
$8^h\ 00^m\ 00^s$	A notch on the E. limb to the naked eye. First contact with shadow certainly past.
$8^h\ 04^m\ 15^s$	Shadow touches W. wall of *Grimaldi.*
$8^h\ 06^m\ 25^s$	Shadow reaches *Aristarchus.*
$8^h\ 11^m\ 55^s$	Shadow reaches *Kepler.* No color visible in shadow.
$8^h\ 13^m\ 00^s$	Shadow reaches E. edge of *Sinus Iridum.*

$8^h\ 15^m$	Tinge of copper on E. limb.
$8^h\ 17^m\ 50^s$	Shadow reaches *Laplace Promontory.*
$8^h\ 18^m\ 46^s$	Shadow reaches *Pytheas.*
$8^h\ 18^m\ 58^s$	Shadow reaches W. wall of *Gassendi.*
$8^h\ 20^m\ 45^s$	Shadow reaches W. wall of *Copernicus* and a small unnamed, but bright crater in south latitude 18°.8 and west longitude 36°.3.
$8^h\ 24^m\ 00^s$	Shadow reaches E. wall of *Plato.*
$8^h\ 24^m\ 28^s$	Shadow reaches *Pico.*
$8^h\ 24^m\ 58^s$	Shadow reaches W. wall of *Plato.*
$8^h\ 26^m\ 10^s$	Shadow reaches E. wall of *Archimedes.*
$8^h\ 30^m\ 10^s$	Shadow reaches *Flammarion.*
$8^h\ 33^m\ 50^s$	Shadow reaches E. wall of *Eudoxus.*
$8^h\ 34^m\ 34^s$	Shadow reaches E. wall of *Eratosthenes.*
$8^h\ 38^m\ 00^s$	Shadow reaches E. wall of *Tycho* and *Menelaus.*
$8^h\ 41^m\ 05^s$	Shadow reaches *Dionysius.*
$8^h\ 43^m\ 35^s$	Shadow reaches E. wall of *Endymion.*
$8^h\ 44^m\ 38^s$	Shadow reaches W. wall of *Endymion.*
$8^h\ 49^m\ 50^s$	Shadow reaches *Censorinus.*
$8^h\ 52^m\ 15^s$	Shadow reaches *Proclus.*
$8^h\ 56^m\ 00^s$	Shadow reaches *Eimmart.*
$8^h\ 58^m\ 10^s$	Shadow reaches *Cape Agarum.*
$9^h\ 07^m\ 55^s$	Totality begins.
$10^h\ 48^m\ 00^s$	Totality ends.
$11^h\ 30^m\ 10^s$	*Menelaus* reappears.
$11^h\ 34^m\ 35^s$	*Plinius* reappears.
$11^h\ 35^m\ 26^s$	W. wall of *Endymion* reappears.
$11^h\ 39^m\ 20^s$	*Censorinus* reappears.
$11^h\ 45^m\ 05^s$	*Proclus* reappears.
$11^h\ 48^m\ 30^s$	*Eimmart* reappears.
$11^h\ 50^m\ 50^s$	*Cape Agarum* reappears.
$11^h\ 54^m\ 10^s$	Shadow goes off.

The following occultations were observed, using a power of about 85:

S. D. -8° 5994.	Disappearance,	$9^h\ 39^m\ 16^s.0$ P. S. T.
11 ± mag. star.	"	$9^h\ 56^m\ 03^s.0$
11 ± mag. star.	"	$9^h\ 57^m\ 08^s.0$
S. D. -8° 5996.	"	$9^h\ 58^m\ 05^s.5$
A star of 11 ± mag.	"	$10^h\ 04^m\ 23^s.7$
S. D. -7° 5900.	"	$10^h\ 09^m\ 37^s.9$
12 to 13 mag. star.	"	$10^h\ 18^m\ 34^s \pm 1^s$.
S. D. -7° 5907.	"	$10^h\ 50^m\ 21^s \pm 1^s$.

Soon after totality commenced, I turned the telescope to the place of SWIFT's comet, but, as it was near the horizon, failed to see it. Just before totality ended, I again turned to the comet's place, and this time found it without difficulty. There was not sufficient time to adjust the micrometer and make an observation.

Its light was about the same as during the latter part of August, but its centre seemed a little more condensed.

C. D. PERRINE.

LICK OBSERVATORY,
September 25, 1895.

TOTAL ECLIPSE OF THE MOON, SEPTEMBER 3, 1895.

The total eclipse of the Moon was observed with a three-inch telescope with alt-azimuth mounting, and the times of contact were noted by a mean time chronometer. The first contact was not observed, and the last contact was observed with the naked eye.

The occultation of several stars was noted, but only one star was bright enough to be well observed.

Fifteen minutes after totality began, all the more prominent features of the Moon's surface could be distinguished easily in the telescope, and even in the middle of the eclipse *Tycho* and a few other craters could be seen clearly. To the naked eye, the contrast between the light and dark areas was well marked throughout the eclipse, the color varying from orange-red to a deep copper-red.

The following edge of the shadow was heavier and more sharply defined than the preceding.

The star occulted was estimated at 9.5 magnitude, in position angle 95° with reference to the Moon's centre. The star was

BD. -8°, 5996 (8.7 mag.). The time of dissappearance was $9^h\ 57^m\ 58^s.3$ P. S. T.

Beginning of totality,	$9^h\ 6^m\ 28^s$ P. S. T.
End of totality,	$10^h\ 47^m\ 35^s$
Last contact with shadow,	$11^h\ 54^m\ 00^s$

R. G. AITKEN.

LICK OBSERVATORY,
September 4, 1895.

LUNAR ECLIPSE, SEPTEMBER 3, 1895.

Beginning of totality, $9^h\ 6^m\ 35^s$ P. S. T.
End of totality, $10^h\ 47^m\ 20^s$.
Observations made without telescopic aid.

W. W. CAMPBELL.

NOTE ON THE MELTING OF THE POLAR CAPS OF *MARS*.

I suppose no fact concerning *Mars* has been better established than the one that the polar caps continue to decrease in size after the summer solstice on the planet has passed. The statement has recently been made, both in an astronomical journal and in the secular press, that the continued diminution of the cap after solstice proves that the maximum temperature on the planet occurs several months after summer solstice, and, therefore, that *Mars* has a "heat-storing atmosphere."

I believe that astronomers have always considered that *Mars* has *some* atmosphere, that the more or less extensive atmosphere is necessarily "heat-storing," and that the maximum temperature necessarily, therefore, occurs some time after summer solstice. But does the continued melting of the caps after solstice prove it? I think not.

Suppose that a given area A of a cap melts off before solstice, leaving a remnant of area B covering the polar region. The area B receives the same amount of direct solar heat before solstice that it does after. If this heat had no effect upon the area B until after summer solstice, then the point would be well taken. But such is not the case. There is abundant positive proof that extensive melting of the area B does occur before solstice; and that it should continue to melt after solstice does not prove that the maximum temperature occurs then, since the same amount of direct solar heat is received after solstice as before.

Melting within the area *B* before solstice is evident from the dark regions which have been observed to form within the cap. An examination of the drawings of the south polar cap at the 1894 opposition will show that large dark areas existed within the cap, in the immediate vicinity of the pole, months before solstice occurred. Thus, the solstice occurred September 1, 1894, with only a small cap of area *B* remaining. Even in May, 1894, three months before solstice, there was a large dark area in the immediate vicinity of the pole, almost as large as the entire remaining area *B* of September 1. If dark areas, presumably formed by melting, appear in the polar regions months before solstice, we would expect the melting to continue over the same area for at least an equal number of months subsequent to solstice; and the fact that it does so is no proof that the maximum heat occurs after solstice.

Again, because a small area *B* remains on September 1, must we assume that the snow or other material forming the cap *B* is then at its original depth? Possibly a half, or two-thirds, or nearly all of the original snow covering *B* has melted before September 1, so that only a thin layer remains to be melted after solstice.

It is well to remark again that astronomers have always believed that whatever atmosphere *Mars* has is necessarily heat-storing, and that the maximum temperature therefore occurs after the solstice; but the continued melting of the caps after solstice neither proves nor disproves it. W. W. C.

THE CŒLOSTAT.

M. LIPPMANN'S recent paper before the French Academy, on the theory of an instrument called the "cœlostat," has created considerable interest abroad [see *The Observatory*, for August], on the supposition that the instrument is new. The principles — and possibly the practice — of the cœlostat are well known in this country. As an example, I may, perhaps, mention that when Professor S. P. LANGLEY was here, in 1893, he recommended that for certain purposes we mount the reflector of our heliostat with its plane in the axis of rotation and parallel to the Earth's axis, adjust the clock-work to a 48-hour rotation, and place the observing telescope in the proper horizontal position. These conditions are identical with those required by M. LIPPMANN'S cœlostat. W. W. C.

MR. LOWELL'S THEORY OF *MARS*.

Although the planet has practically withdrawn from observation for a time, the popular interest in it has by no means disappeared, but has been maintained, and perhaps even increased, by the bold speculations of Mr. LOWELL, presented last season in his captivating lectures, and since then in his charming papers published in the *Atlantic Monthly*.

The observations of 1894 have made it practically certain that the so-called "canals" are real, whatever may be their explanation; and that great changes in their appearance, and in that of other more conspicuous features of the planet's surface, followed progressively as the white cap at the southern pole of *Mars* waned and vanished. The spectroscopic observations of CAMPBELL also proved that the planet's atmosphere must be very rare as compared with ours, and not heavily charged with water vapor. So much is fairly ascertained.

Mr. LOWELL goes much farther. For him the polar-cap is surely snow or ice, and its disappearance is due to unquestionable melting. Since the telescope gives no evidence of mountain peaks and ranges, he concludes, moreover, that the planet's surface is practically one dead level, over which the waters from the melting ice-cap find their way to the equatorial regions, carrying fertility with them; the dark regions of the southern hemisphere, in his view, are not "seas," as hitherto supposed and as their names imply, but lands covered with forests or other forms of vegetation, while the ruddy northern regions are barren deserts; perhaps, if the writer may be allowed to add a suggestion of his own, old ocean bottoms, depressed below the general level, like the Caspian, or the basin of Sahara. In Mr. LOWELL's judgment, the "canals" mark real watercourses, and these he believes to be artificial, because of their perfect straightness and evenness, and the design apparent in the way their numerous intersections are arranged. When the life-giving water reaches these channels, vegetation springs up on either side, and especially at their junctions, where the round, dark spots formerly called lakes are by him transformed into "oases." It is the vegetation that we see — not the watercourses themselves. As to the curious doubling or "germination" of many of the canals, he confesses himself still at fault.

As to the "artificiality" of the canals, he argues that the people who inhabit ***Mars*** ought to be gigantic, because there the lessened force of gravity (only about a third as great as on the Earth) enlarges for all animals the limit of advantageous size, and, moreover, makes a giant's labor three times as effective as it would be on the Earth; so that, as a canal-maker, one Martian might be equivalent to a hundred Italians. Then, too, since his world is probably much older than our own, he may already have all the knowledge and appliances that human engineers will acquire in the distant future.

Against all which, to mention nothing else, stands the fundamental doubt whether so small a globe as ***Mars***, with so rare an atmosphere, and receiving from the Sun only half as much heat to each square mile as does the Earth, can possibly maintain anywhere a temperature even as high as that which prevails on the summits of our loftiest mountains; whether, in fact, the polar-caps are made of frozen water or of some very different substance.— C. A. YOUNG, in *The Cosmopolitan*, October, 1895.

THE FLOWER OBSERVATORY, UNIVERSITY OF PENNSYLVANIA.

The University of Pennsylvania has begun the erection of an Astronomical Observatory, the purpose being to furnish facilities for instruction in astronomy and for original research. The site is five miles west of the present University buildings, being two miles beyond the city limits.

The principal instruments are an 18-inch equatorial, with spectroscope, a meridian circle, and a zenith telescope, each of 4 inches aperture. The optical parts are by BRASHEAR, the instrumental by WARNER & SWASEY.

As the Observatory Library is for the most part a thing of the future, any of your publications relating to astronomy or allied subjects which you may be prepared to send us, will be very acceptable. At present we have nothing to offer in exchange, but hope we may have at a future time.

Contributions may be sent to the Flower Observatory, University of Pennsylvania, Philadelphia. C. L. DOOLITTLE, Professor of Astronomy.

COMET NOTES.

A faint comet was discovered by Dr. SWIFT of LOWE Observatory on August 20th, in the constellation *Pisces.* Professor Boss of Albany has just published (in *Astronomical Journal,* No. 355) the elements of its orbit, basing them upon all the available observations up to date. He finds that the orbit is an ellipse; that the comet completes one revolution in its orbit in about 7¼ years, and that its least distance from the Sun was reached about August 20th. The comet is rapidly diminishing in brightness, and is already a difficult object to see.

A telegram received at Mt. Hamilton states that FAYE'S periodic comet has been found again. Its period is about 7½ years.

Both SWIFT'S and FAYE'S comets belong to the *Jupiter* family of comets. W. W. C.

Minutes of the Meeting of the Board of Directors, held at the Lick Observatory, September 7, 1895.

President **Burckhalter** took the chair, and a quorum was present. The minutes of the last meeting were approved. The following members were duly elected:

List of Members Elected September 7, 1895.

Mr. **Wilbert M. Birge**	Davenport, Neb.
Mr. J. M. **Brosius**	Napa, Cal.
Mr. A. D. **Campbell**	Campbell, Santa Clara Co., Cal.
Mr. **David E. Hadden**	Alta, Iowa.
Mr. **George W. Percy**	318 Boulevard Terrace, Oakland, Cal.
Mr. **Chas. J. Welch**	1090 Eddy St., San Francisco, Cal.

On motion it was

Resolved, That the Library Committee be instructed to draft a suitable circular to be sent to the exchanging institutions regarding non-receipt of exchanges.

Resolved, That the Library Committee be instructed to make suitable arrangements with the California Academy of Sciences for the care of the Society's library.

Adjourned.

Minutes of the Meeting of the Astronomical Society of the Pacific, held at the Lick Observatory, September 7, 1895.

President **Burckhalter** presided. The minutes of the last meeting, as printed in the *Publications*, were approved.

The Secretary read the names of members duly elected at the meeting of the Directors.

The following papers were presented:

1. When the Moon runs furthest north and furthest south, by Miss **Rose O'Halloran**, of San Francisco.
2. Foucault's Pendulum Experiment, by Mr. **Torvald Kohl**, of Odder, Denmark.
3. Planetary Phenomena for September and October, 1895, by Professor **Malcolm McNeill**, of Lake Forest University.
4. Photographs of Sunsets at Mt. Hamilton in 1893, by Mr. A. L. **Colton**.
5. Eclipse of *Jupiter's* Fourth Satellite, 1895, April 11, by Mr. **John Tebbutt**, F. R. A. S., of New South Wales.
6. A new circuit-breaker for astronomical clocks, by Mr. A. F. **Poole**, of Stanford University.
7. Note on a Cause of Differences between Drawings and Photographs of Nebulae, by Professor J. E. **Keeler**.

Adjourned.

OFFICERS OF THE SOCIETY.

Chas. Burckhalter (Chabot Observatory, Oakland),	*President*
W. J. Hussey (Leland Stanford Jr. University, Palo Alto, Cal.), E. S. Holden (Lick Observatory) O. von Geldern (819 Market Street, S. F.),	*Vice-Presidents*
C. D. Perrine (Lick Observatory),	*Secretary*
F. R. Ziel (410 California Street, S. F.),	*Secretary and Treasurer*

Board of Directors—Messrs. Burckhalter, Holden, Hussey, Molera, Miss O'Halloran, Messrs. Perrine, Pierson, Schaeberle, Stringham, von Geldern, Ziel.

Finance Committee—Messrs. von Geldern, Pierson, Stringham.

Committee on Publication—Messrs. Holden, Campbell, Babcock.

Library Committee—Mr. Molera, Miss O'Halloran, Mr. Babcock.

Committee on the Comet-Medal—Messrs. Holden *(ex-officio)*, Schaeberle, Hussey.

OFFICERS OF THE CHICAGO SECTION.

Executive Committee—Ruthven W. Pike.

OFFICERS OF THE MEXICAN SECTION.

Executive Committee—Camilo Gonzalez, Francisco Rodriguez Rey, Agustin Aragon

NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the *calendar* year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our book-keeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific 819 Market Street, San Francisco.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 819 Market Street, San Francisco, who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed rests with the writers, and is not assumed by the Society itself.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend any or all of the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific" at the rooms of the Society, 819 Market Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

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REVIEW OF SOLAR OBSERVATIONS, 1891 TO 1895 (JUNE).

BY DAVID E. HADDEN.

Systematic observations of the Sun's surface were begun on August 1, 1890, and have been continued to the present time. During this time I have observed the solar disc on 960 days and have kept a complete record of the number of groups of spots, the total number of spots in these groups, and the number of faculæ or groups of faculæ, their relative size, location, and place of origin, whether on the visible disc, or appearing by rotation.

These observations have been published monthly in *The Review of the Iowa Weather and Crop Service*, and occasionally in a few other journals.

Most of this work was done with a 3-inch BRASHEAR telescope of Jena glass, using various eye-pieces, powers, and shade glasses. Latterly, I have given preference to the Herschelian wedge, using ½-inch and ¾-inch eye-pieces and neutral green shade glass. The method of projection has also been much employed.

During the past year some observations of the prominences have been made with the spectroscope, using a 2-inch ROWLAND grating of 14,438 lines to the inch.

A few photographs about three inches in diameter were taken, and numerous pencil sketches of the larger and more remarkable groups were made.

The following tables exhibit the results of some of these observations for the years 1891 to 1894 inclusive, and a portion of 1895:

RESUMÉ OF SOLAR OBSERVATIONS, ALTA, IOWA.

MONTHS.	NUMBER OF OBSERVING DAYS.	MEAN DAILY NUMBER OF		
		GROUPS.	SPOTS.	FACULÆ.
1891.				
January	25	1.0	2.7	1.7
February	20	1.6	7.3	1.3
March	21	1.1	2.5	2.2
April	23	1.9	12.2	3.1
May	28	3.6	16.8	4.1
June	17	4.2	16.9	5.3
July	24	3.5	26.1	5.7
August	18	2.2	13.0	4.4
September	23	4.0	23.1	5.2
October	23	4.6	19.5	3.6
November	17	3.8	23.1	3.6
December	18	3.4	15.6	3.1
1892.				
January	24	5.8	28.0	4.1
February	13	5.0	46.0	3.5
March	14	3.2	14.0	3.1
April	13	4.6	21.5	4.6
May	5	5.6	30.0	2.6
June	23	6.0	35.0	4.4
July	22	6.2	56.9	4.4
August	23	7.6	38.4	5.1
September	18	5.3	30.2	5.7
October	22	5.7	41.6	4.6
November	15	4.7	35.4	3.2
December	13	7.4	31.1	4.0
1893.				
January	13	6.1	42.3	3.5
February	15	5.1	42.4	3.4
March	17	5.1	30.0	3.3
April	15	7.3	31.5	3.9
May	19	8.1	31.5	4.5
June	8	7.0	46.7	4.6
July	22	7.4	49.3	4.4
August	21	9.4	53.8	4.7
September	24	6.1	34.6	4.4
October	10	6.7	30.7	4.7
November	7	6.6	24.7	4.0
December	6	4.8	21.7	3.0
1894.				
January	9	7.2	40.0	3.7
February	19	6.4	26.6	2.9
March	8	4.6	21.0	3.8
April	7	5.3	25.4	3.7
May	13	6.1	33.5	3.0
June	20	6.8	30.3	3.4
July	20	7.3	34.6	3.8
August	13	4.5	22.1	3.2
September	10	4.7	17.5	3.3
October	12	4.6	34.6	3.6
November	7	4.4	16.6	2.8
December	1	5.0*	28.0*	4.0*

* Only one observation.

1895.

MONTHS.	NUMBER OF OBSERVING DAYS.	MEAN DAILY NUMBER OF		
		GROUPS.	SPOTS.	FACULÆ.
January	6	4.2		4.2
February	11	5.3	23.6	3.5
March	13	5.4	25.7	4.0
April	5	6.6	32.8	4.8
May	7	6.0	34.9	4.1
June	10	5.6	43.1	3.6

When the daily average number of Sun-spots is plotted graphically, marked fluctuations are noticed during the entire five years, but generally there is a constant increase in the number of spots during the period.

A small maximum appeared in July, 1891, and two maxima in 1892, viz: in February and July, that of July being the highest during the five years.

A secondary maximum was noted in the summer of 1893, commencing in the month of June and reaching the last maximum in August. After this, a steady decline set in, with slight irregular fluctuations during 1894 and first half of 1895.

The following are among the largest and more remarkable Sun-spot groups in the period under review:

August 29, 1891. A group containing one large spot is on the east limb. A very brilliant aurora was observed in the evening. On the following day the umbra was crossed with bright streaks.

August 31. Unusual activity in group, which has developed into two immense groups containing many large spots. Bright aurora visible last evening and to-night.

September 3. The large groups are now on the central meridian and are very fine, being visible to the naked eye. Aurora again to-night.

On September 6th the groups were breaking up into smaller spots and passed over the west limb on the 9th. The return of this disturbed area at the southeast limb on September 25th was again attended by brilliant auroras for several evenings.

January 18, 1892. Ten groups of spots are visible to-day, two very fine groups of well-defined umbra and penumbra.

January 19th. Eleven groups to-day.

February 5. An immense group of many large spots is just appearing by solar rotation.

February 7th. The great group is very fine, being easily visible to the naked eye. It consists of a very large penumbral area containing two large black nuclei and smaller spots surrounding. This group underwent many changes from day to day, but still consisted of the two nuclei when it disappeared by solar rotation on the west limb, on the 18th, completing the transit in about thirteen and a half days. It was the largest group seen on the solar disc in nearly twenty years.

June 18. A fine group of large spots has appeared at east limb. Great activity on solar surface to-day; five groups are large, ten spots have fine umbra and penumbra.

June 19th. About 100 spots were counted in the six groups to-day. One large group in south latitude has a fine elongated nucleus, which on the 22d had divided into four parts and increased in extent, but was now less active and breaking up.

The month of July, 1892, witnessed another very fine display of solar activity, accompanied by some magnificent manifestations of terrestrial electricity.

On July 5th two large groups were noted near the east limb; the one northeast has an immense spot, the umbra of which is dividing into several parts. Many large groups appeared on the 7th, and 126 spots were counted on the 8th.

On the 10th several large enlongated nuclei were observed in the groups in southeast quadrant; the largest group is breaking up into a large number of small spots.

On the 12th it was near the west limb still containing two fine nuclei, but the penumbral area is fast closing up the smaller spots surrounding it.

Three new groups formed on the 16th in various places, both north and south latitudes, and in the evening one of the finest displays of Northern lights observed in many years was noticed.

On the 25th many large groups again appeared, and the Sun's surface was dotted with ten to thirteen groups until the close of the month.

The month of August, 1893, was also rich in fine groups.

On the 3d considerable disturbance was noticed in the groups near the east limb in south solar latitude, which were increasing in size and number, and by the 5th had developed unusual activity; the region now contained an immense double group of very large penumbra and large nuclei, which was readily visible to the naked eye. A slight aurora was visible to-night.

This group was about on the central meridian on the 6th, its appearance remaining about the same as on yesterday. A beautiful aurora was seen this evening.

On the 8th the large group is a superb object, being still easily visible to the naked eye, and its nuclei increasing some in size; the solar surface is completely spotted and a pretty sight.

On the 9th the large group is on the wane, the penumbra and nucleus breaking up; decreasing much in size on the 11th, but still a fine object when it disappeared by solar rotation on the 12th. It was the largest and finest group seen on the disc since the great group of February, 1892.

January 14 to 21, 1894. A large group is in the southern hemisphere visible to the naked eye.

February 15. Large group appeared by rotation to-day, which proved very interesting. The group was of an oval form with several nuclei; before disappearing at west limb, it decreased much in size and extent.

On the 19th, the $H\alpha$ line was brilliantly reversed in the umbra of this group; when the slit was widely opened the reversal had a flame or tree-like appearance.

Slight reversals were also observed on the 21st.

On the 25th the penumbra of the group was the location ot bright reversals of the $H\alpha$ line, more especially north and southwest of the umbra, the umbra itself not appearing to be affected.

May 15 to June 5. Several large interesting groups made the transit of the disc during this period. They were still of large size and interesting during their next return from June 12th to 20th.

June 7. A remarkable eruptive prominence was observed this afternoon. At 5:15 P.M., an intensely brilliant prominence was noticed on the southeast limb, having the appearance of "spikes" and "flames." It seemed to be in violent commotion, as I found it almost impossible to delineate it. I estimated its height at about 70,000 miles. It was also very bright in D_3 and $H\beta$ lines. In about ten minutes the entire disturbance had nearly subsided, but a few faint flames remaining and a bright mass of "debris," which rested partly on and within the limb. The $H\alpha$ line was shifted much toward the blue end, indicating a rapid approach towards us. At 6 P.M. but little remained of this great disturbance, but turning my attention farther in on the disc, I found the entire region from the southeast limb to the west portion of the group of spots (which was about two days in), to be in a violently agitated condition. At numerous points in this region, the $H\alpha$ line appeared with one or more dark, vibrating tongues or blow-pipe looking jets, directed towards the red end of the spectrum.

October 1 to 12. An extensive group appeared by rotation and made the transit of the disc, increasing much in size during its progress.

On the 10th an interesting feature of the group was a large square penumbral spot containing four large nuclei.

October 6. Much disturbance observed in $H\alpha$ line in the large group; several distortions towards blue end of spectrum, and reversals of $H\alpha$ line near the large group.

January 28, 1895. Reversals and distortions of $H\alpha$ line around the groups east of meridian.

April 28. All the groups on the Sun's disc to-day are large.

June 6. Active small protuberances near the new group on east limb; the region of spots and faculæ surrounding are also much disturbed.

June 16. Disturbances in and around the large group in northern hemisphere; reversals and distortions of $H\alpha$ line; bright stemmed prominence near a group on southeast limb.

The following tables give the maximum and minimum number of Sun-spot groups observed on any day for the months and years indicated:

MAXIMUM DAILY NUMBER OF SUN-SPOT GROUPS.

MONTHS.	1890.	1891.	1892.	1893.	1894.	1895.
January . .		4	11	11	10	7
February .		3	8	9	8	9
March . . .		2	6	10	8	8
April . . .		4	7	10	7	8
May		5	7	11	9	10
June. . . .		7	9	11	9	7
July		8	13	10	11	
August . .	2	5	10	14	8	
September.	2	8	9	9	9	
October . .	2	5	8	12	7	
November .	4	8	9	9	6	
December .	3	7	13	9		

MINIMUM DAILY NUMBER OF SUN-SPOT GROUPS.

MONTHS.	1890.	1891.	1892.	1893.	1894.	1895.
January . .		0	2	2	4	3
February .		0	1	2	4	3
March . . .		0	1	3	3	4
April . . .		1	2	4	3	5
May		2	4	6	3	1
June . . .		1	4	5	5	4
July		2	3	4	4	
August . .	0	0	4	6	2	
September.	0	1	3	4	2	
October . .	0	3	2	5	2	
November .	0	2	3	4	3	
December .	0	1	2	2		

ALTA, IOWA, October 9, 1895.
Latitude, 42° 40′ N.
Longitude, 6h. 21m. W.

DOUBLE-STAR MEASURES.

By R. G. AITKEN.

The following measures were made with the twelve-inch equatorial of this observatory. The position angle is usually the mean of four settings, and the distance that of three (occasionally four) double-distances. The position of the stars is given for 1880.0. The seeing is estimated by a scale on which 5 stands for the best conditions. The eye-piece used in most of the measures has a power of 545 diameters; but a few measures were made with lower powers.

Σ 13.

R. A. $0^h\ 9^m\ 25^s$. Decl. +76° 17′.

	θ_0	ρ_0	MAGNITUDE.	SEEING.
1895.664	81°.7	0″.73	6.2 - - 6.2	4+
1895.681	84 .3	0 .81	6.2 - - 6.2	3+
1895.692	86 .4	0 .79	6.2 - - 6.3	3
1895.68	84°.1	0″.78	6.2 - - 6.2	

Σ 60 (*η Cassiopeiæ*).

R. A. $0^h\ 41^m\ 51^s$. Decl. +57° 18′.

	θ_0	ρ_0	MAGNITUDE.	SEEING.
1895.664	203°.1	4″.96	4 - - - 7.8	4
1895.672	204 .1	5 .06	4 - - - 7.5	3+
1895.681	205 .1	4 .75	4 - - - 7.5	4+
1895.67	204°.1	4″.92	4 - - - 7.6	

β 120 (*ν Scorpii*).

R. A. $16^h\ 5^m\ 1^s$. Decl. −19° 9′.

		A B.		
1895.462	0°.5	0″.88	6 - - - 6.5	3
1895.489	5 .2	0 .75	6 - - - 6.5	2+
1895.505	2 .7	0 .79	6 - - - 6.5	3+
1895.48	2°.8	0″.81	6 - - - 6.5	
		C D.		
1895.462	44°.2	1″.90	7.0 - - 8.5	3
1895.489	42 .7	1 .87	7.5 - - 8.5	2+
1895.500	40 .9	1 .90	7.0 - - 8.0	2+
1895.48	42°.6	1″.89	7.2 - - 8.3	

β 624.

R. A. $16^h\ 15^m\ 41^s$. Decl. −22° 50′.

1895.615	315°.4	1″.29	8 - - 9.2	4
1895.634	318 .5	1 .08	8.2 - - 9.8	4
1895.642	314 .3	1 .07	8.1 - - 9.8	3
1895.63	316°.1	1″.15	8.1 - - 9.6	

β 241.

R. A. $16^h\ 48^m\ 24^s$. Decl. −21° 22′.

1895.615	164°.9	0″.80	7 - - - 7.1	3+
1895.634	161 .3	0 .60	7 - - - 7.3	3+
1895.642	160 .1	0 .73	7 - - - 7.1	3
1895.63	162°.1	0″.71	7 - - - 7.2	

β 357.

R. A. $16^h\ 59^m\ 52^s$. Decl. +10° 43′.

1895.519	304°.3	1″.24	8.0 - - 9.3	3+
1895.527	299 .6	1 .38	8.3 - - 9.2	2+
1895.598	303 .5	1 .32	8.3 - - 9.4	3+
1895.55	302°.5	1″.31	8.2 - - 9.4	

β 823.

R. A. $17^h\ 0^m\ 29^s$. Decl. +0° 49′.

	θ_0	ρ_0	MAGNITUDE.	SEEING.
1895.634	6°.0	0″.77	8.4 - - 9.3	3+
1895.642	4 .4	0 .99	8.1 - - 9.3	3
1895.738	8 .7	0 .79	8.3 - - 9.5	3+
1895.67	6°.4	0″.85	8.3 - - 9.4	

E. E. B. No. ?.

R. A. $17^h\ 7^m\ 38^s$. Decl. −8° 16′.

1895.481	144°.9	2″.05	. . . . . .	4
1895.519	147 .6	2 .12	7.8 - 12.0	4
1895.598	154 .1	2 .02	8.2 - 12.4	3+
1895.53	148°.9	2″.06	8.0 - 12.2	

Σ 2140 (α *Herculis*).

R. A. $17^h\ 9^m\ 10^s$. Decl. +14° 32′.

1895.462	115°.3	4″.77	3.5 - - 6.0	3
1895.470	114 .0	4 .81	. . . . . .	4
1895.480	113 .5	4 .96	3.5 - - 6.0	4
1895.47	114°.3	4″.85	3.5 - - 6.0	

β 1121. (B. D. +12° 3264.)

R. A. $17^h\ 31^m\ 52^s$. Decl. +12° 37′.

1895.634	235°.6	0″.56	8.3 - - 9.5	3+
1895.681	236 .1	0 .70	8.5 - - 9.5	4+
1895.708	236 .2	0 .58	8.5 - - 9.5	3
1895.67	236°.0	0″.61	8.4 - - 9.5	

A. C. 7.

R. A. $17^h\ 41^m\ 47^s$. Decl. +27° 48′.

1895.505	43°.6	1″.10	10 - 10	3
1895.514	45 .3	1 .17	10 - 10.2	4
1895.708	43 .9	1 .14	10 - 10	3+
1895.58	44°.3	1″.14	10 - 10.1	

H_I 41.

R. A. $17^h\ 42^m\ 17^s$. Decl. +72° 59′.

1895.653	337°.1	1″.41	7.8 - - 8.0	3
1895.672	337 .9	1 .43	7.8 - - 8.0	4+
1895.681	340 .1	1 .43	7.8 - - 8.0	4
1895.67	338°.4	1″.42	7.8 - - 8.0	

β 47.

R. A. $17^h\ 54^m\ 32^s$. Decl. −10° 14′.

	θ_0	ρ_0	MAGNITUDE.	SEEING
1895.615	278°.0	1″.57	8.2 - 10.4	4+
1895.634	277 .5	1 .45	7.8 - 10.5	4
1895.642	275 .9	1 .38	8.0 - 10.4	3
1895.63	277°.1	1″.46	8.0 - 10.4	

β 283. (B. A. C. 6088.)

R. A. $17^h\ 54^m\ 38^s$. Decl. −22° 47′.

1895.514	237°.7	8″.69	6 - - - 13	4
1895.519	237 .1	8 .21	6.3 - - 13	4
1895.598	238 .2	8 .44	6 - - - 13	3
1895.54	237°.7	8″.45	6.1 - - 13	

β 1127. (Groombr. 2500.)

R. A. $17^h\ 58^m\ 59^s$. Decl. +44° 13′.

1895.598	147°.6	0″.90	8 - - 10.0	3
1895.615	146 .5	0 .90	8 - - 10.2	3+
1895.738	148 .2	0 .77	7.5 - 10.5	4
1895.65	147°.4	0″.86	7.8 - 10.2	

Σ 2272. (70 *Ophiuchi.*)

R. A. $17^h\ 59^m\ 23^s$. Decl. +2° 33′.

1895.481	300°.6	2″.43	4 - - - 8	3
1895.681	298 .1	2 .29	3.5 - - 7.3	4
1895.692	298 .3	2 .26	3.5 - - 7.5	3
1895.62	299°.0	2″.33	3.7 - - 7.6	

β 132.

R. A. $18^h\ 4^m\ 7^s$. Decl. −19° 52′.

1895.514	222°.6	0″.83	7 - - - 7.2	3+
1895.519	220 .5	0 .73	7 - - - 7.4	3+
1895.598	224 .0	0 .75	7 - - - 7.2	3
1895.54	222°.4	0″.77	7 - - - 7.3	

β 465.

R. A. $18^h\ 41^m\ 38^s$. Decl. +56° 45′.

	θ_0	ρ_0	MAGNITUDE.	SEEING.
1895.598	292°.1	3″.15	8 - - 10.1	3+
1895.609	291 .4	3 .20	8 - - 10.5	3
1895.730	294 .9	3 .04	8.3 - 10.5	3+
1895.64	292°.8	3″.13	8.1 - 10.4	

β 1135. (L. 39561.)

R. A. $20^h\ 25^m\ 10^s$. Decl. +45° 20′.

1895.749	338°.4	1″.34	8 - - 11.0	3
1895.768	333 .2	1 .22	8 - - 11.5	4+
1895.815	338 .7	1 .64	8.3 - 11.8	3
1895.78	336°.8	1″.40	8.1 - 11.4	

β 1036. (Yarn. 9529.)

R. A. $21^h\ 40^m\ 59^s$. Decl. −17° 51′.

1895.749	209°.8	4″.61	8 - - 11.5	3+
1895.790	209 .4	4 .68	8 - - 11.5	4
1895.815	208 .5	4 .82	8 - - 12.0	3
1895.78	209°.2	4″.70	8 - - 11.7	

Σ 3012–13.

R. A. $23^h\ 21^m\ 34^s$. Decl. +15° 58′.

A B.

1895.768	267°.3	3″.05	7.8 - - 9.5	4+
1895.812	272 .1	2 .98	7.8 - - 9.3	4+
1895.815	270 .2	2 .67	7.8 - - 9.3	3
1895.80	269°.9	2″.90	7.8 - - 9.4	

C D.

1895.768	188°.4	2″.35	8.7 - - 8.8	4+
1895.812	191 .6	2 .54	8.7 - - 8.8	4+
1895.815	188 .0	2 .38	8.7 - - 8.8	3
1895.80	189°.3	2″.42	8.7 - - 8.8	

A C.

1895.768	243°.6	52″.54	7.8 - - 8.7	4+
1895.812	244 .5	53 .82	7.8 - - 8.7	4+
1895.815	244 .2	54 .31	7.8 - - 8.7	3
1895.80	244°.1	53″.56	7.8 - - 8.7	

β 47.

R. A. 17ʰ 54ᵐ 32ˢ. Decl. − 10° 14′.

	θ_0	ρ_0	MAGNITUDE.	SEEING
1895.615	278°.0	1″.57	8.2 - 10.4	4+
1895.634	277 .5	1 .45	7.8 - 10.5	4
1895.642	275 .9	1 .38	8.0 - 10.4	3
1895.63	277°.1	1″.46	8.0 - 10.4	

β 283. (B. A. C. 6088.)

R. A. 17ʰ 54ᵐ 38ˢ. Decl. − 22° 47′.

1895.514	237°.7	8″.69	6 - - - 13	4
1895.519	237 .1	8 .21	6.3 - - 13	4
1895.598	238 .2	8 .44	6 - - - 13	3
1895.54	237°.7	8″.45	6.1 - - 13	

β 1127. (Groombr. 2500.)

R. A. 17ʰ 58ᵐ 59ˢ. Decl. + 44° 13′.

1895.598	147°.6	0″.90	8 - - 10.0	3
1895.615	146 .5	0 .90	8 - - 10.2	3+
1895.738	148 .2	0 .77	7.5 - 10.5	4
1895.65	147°.4	0″.86	7.8 - 10.2	

Σ 2272. (70 *Ophiuchi.*)

R. A. 17ʰ 59ᵐ 23ˢ. Decl. + 2° 33′.

1895.481	300°.6	2″.43	4 - - - 8	3
1895.681	298 .1	2 .29	3.5 - - 7.3	4
1895.692	298 .3	2 .26	3.5 - - 7.5	3
1895.62	299°.0	2″.33	3.7 - - 7.6	

β 132.

R. A. 18ʰ 4ᵐ 7ˢ. Decl. − 19° 52′.

1895.514	222°.6	0″.83	7 - - - 7.2	3+
1895.519	220 .5	0 .73	7 - - - 7.4	3+
1895.598	224 .0	0 .75	7 - - - 7.2	3
1895.54	222°.4	0″.77	7 - - - 7.3	

β 465.

R. A. $18^h\ 41^m\ 38^s$. Decl. +56° 45′.

	θ_0	ρ_0	MAGNITUDE.	SEEING.
1895.598	292°.1	3″.15	8 - - 10.1	3+
1895.609	291 .4	3 .20	8 - - 10.5	3
1895.730	294 .9	3 .04	8.3 - 10.5	3+
1895.64	292°.8	3″.13	8.1 - 10.4	

β 1135. (L. 39561.)

R. A. $20^h\ 25^m\ 10^s$. Decl. +45° 20′.

1895.749	338°.4	1″.34	8 - - 11.0	3
1895.768	333 .2	1 .22	8 - - 11.5	4+
1895.815	338 .7	1 .64	8.3 - 11.8	3
1895.78	336°.8	1″.40	8.1 - 11.4	

β 1036. (Yarn. 9529.)

R. A. $21^h\ 40^m\ 59^s$. Decl. −17° 51′.

1895.749	209°.8	4″.61	8 - - 11.5	3+
1895.790	209 .4	4 .68	8 - - 11.5	4
1895.815	208 .5	4 .82	8 - - 12.0	3
1895.78	209°.2	4″.70	8 - - 11.7	

Σ 3012–13.

R. A. $23^h\ 21^m\ 34^s$. Decl. +15° 58′.

A B.

1895.768	267°.3	3″.05	7.8 - - 9.5	4+
1895.812	272 .1	2 .98	7.8 - - 9.3	4+
1895.815	270 .2	2 .67	7.8 - - 9.3	3
1895.80	269°.9	2″.90	7.8 - - 9.4	

C D.

1895.768	188°.4	2″.35	8.7 - - 8.8	4+
1895.812	191 .6	2 .54	8.7 - - 8.8	4+
1895.815	188 .0	2 .38	8.7 - - 8.8	3
1895.80	189°.3	2″.42	8.7 - - 8.8	

A C.

1895.768	243°.6	52″.54	7.8 - - 8.7	4+
1895.812	244 .5	53 .82	7.8 - - 8.7	4+
1895.815	244 .2	54 .31	7.8 - - 8.7	3
1895.80	244°.1	53″.56	7.8 - - 8.7	

β 733. (85 *Pegasi.*)

R. A. $23^h\ 55^m\ 52^s$. Decl. +26° 27′.

A B.

	θ_0	ρ_0	MAGNITUDE.	SEEING.
1895.681	186°.2	0″.73	5.5 - 12.0	4+
1895.692	188 .2	0 .88	5.6 - 11.5	2+
1895.702	185 .6	0 .86	5.6 - 12.0	2+
1895.708	184 .4	0 .91	5.5 - 12.0	3
1895.730	182 .4	0 .86	5.5 - 11.5	4
1895.738	188 .2	0 .91	5.5 - 11.5	4+
1895.71	185°.8	0″.86	5.5 - 11.8	

A C.

1895.672	348°.3	29″.27	5.5 - - 8.8	4+
1895.681	348 .6	29 .36	5.5 - - 8.6	4+
1895.692	349 .2	29 .17	5.6 - - 9.0	2+
1895.68	348°.7	29″.27	5.5 - - 8.8	

β 997. (L. 47215.)

R. A. $23^h\ 58^m\ 46^s$. Decl. +45° 1′.

1895.681	337°.5	4″.23	7.8 - - 8.8	4+
1895.692	340 .7	4 .06	8.0 - - 9.2	2+
1895.702	341 .1	4 .08	8.0 - - 9.2	2
1895.69	339°.8	4″.12	7.9 - - 9.1	

O Σ 547.

R. A. $23^h\ 59^m\ 12^s$. Decl. +45° 9′.

1895.672	124°.4	4″.51	7.8 - - 7.8	4
1895.681	124 .2	4 .33	7.8 - - 7.8	4+
1895.692	124 .4	4 .29	8 - - 8	3
1895.68	124°.3	4″.38	7.9 - - 7.9	

LICK OBSERVATORY, October 28, 1895.

PLANETARY PHENOMENA FOR JANUARY AND FEBRUARY, 1896.

By Professor Malcolm McNeill.

January, 1896.

The Earth is in perihelion at about 10 A. M., P. S. T., January 1st.

Mercury is an evening star throughout the month, and comes to greatest eastern elongation at about midnight on January 23d. At this time it sets about an hour and a half later than the Sun, and from about January 12th to the end of the month it sets at least an hour later; so it is in good position for evening observation. The Moon passes south of *Mercury* on January 15th, the day after full moon, but the time of nearest approach does not occur until after both have set for all portions of the United States. The Moon will occult the planet in portions of the South Pacific Ocean.

Venus is still a morning star, rising from three and one-half to two and one-half hours before the Sun. During the month it comes a little nearer to the Sun, but their relative distance does not vary much. It moves rapidly eastward and a little southward through the constellations *Scorpio* and *Sagittarius*.

Mars is also a morning star, rising about two hours before the Sun. It is moving eastward in the constellation *Sagittarius*, and has begun to come nearer to us, although still distant from us more than twice the mean distance of the Earth from the Sun.

Jupiter is coming to good position for observation, rising before 7 P. M. on January 1st, and more than two hours earlier at the end of the month. It is in opposition on the morning of January 24th. It is moving westward (retrograding) in the constellation *Cancer*. At the beginning of the month it is about the Moon's diameter distant from the fourth magnitude star δ *Cancri*, and it moves about four degrees westward before the close of the month.

Saturn is still a morning star, but rises earlier than before. During the month it moves about two degrees eastward in the constellation *Libra*. The rings are wider open than during 1895, the minor axis being rather more than one-third of the major.

Uranus is a morning star, rising rather more than half an hour later than Saturn. It is moving eastward near the boundary of the constellations *Libra* and *Scorpio*.

Neptune is in the constellation *Taurus*, and is above the horizon until nearly sunrise.

EXPLANATION OF THE TABLES.

The phases of the Moon are given in Pacific Standard time. In the tables for Sun and planets, the second and third columns give the Right Ascension and Declination for Greenwich noon. The fifth column gives the local mean time for transit over the Greenwich meridian. To find the local mean time of transit for any other meridian, the time given in the table must be corrected by adding or subtracting the change per day, multiplied by the fraction whose numerator is the longitude from Greenwich in hours, and whose denominator is 24. This correction is seldom much more than 1^m. To find the standard time for the phenomenon, correct the local mean time by *adding* the difference between standard and local time if the place is west of the standard meridian, and *subtracting* if east. The same rules apply to the fourth and sixth columns, which give the local mean times of rising and setting for the meridian of Greenwich. They are roughly computed for Lat. 40°, with the noon Declination and time of meridian transit, and are intended as only a rough guide. They may be in error by a minute or two for the given latitude, and for latitudes differing much from 40° they may be several minutes out.

PHASES OF THE MOON, P. S. T.

		H. M.
Last Quarter,	Jan. 7,	7 25 A. M.
New Moon,	Jan. 14,	2 19 P. M.
First Quarter,	Jan. 22,	6 42 P. M.
Full Moon,	Jan. 30,	12 55 A. M.

THE SUN.

1896.	R. A. H. M.	Declination. ° ′	Rises. H. M.	Transits. H. M.	Sets. H. M.
Jan. 1.	18 46	− 23 2	7 24 A M.	12 4 P.M.	4 44 P.M.
11.	19 30	− 21 50	7 23	12 8	4 53
21.	20 13	− 19 57	7 19	12 11	5 3
31.	20 55	− 17 26	7 12	12 14	5 16

MERCURY.

1896.	R. A. H. M.	Declination. ° ′	Rises. H. M.	Transits. H. M.	Sets. H. M.
Jan. 1.	19 17	— 24 23	8 1 A.M.	12 35 P.M.	5 9 P.M.
11.	20 27	— 21 8	8 19	1 5	5 51
21.	21 27	— 15 42	8 17	1 26	6 35
31.	21 50	— 11 2	7 44	1 9	6 34

VENUS.

Jan. 1.	15 39	— 16 49	3 53 A.M.	8 57 A.M.	2 1 P.M.
11.	16 27	— 19 20	4 10	9 5	2 0
21.	17 17	— 21 6	4 28	9 16	2 4
31.	18 9	— 21 57	4 44	9 28	2 12

MARS.

Jan. 1.	16 52	— 22 44	5 28 A.M.	10 9 A.M.	2 50 P.M.
11.	17 23	— 23 30	5 23	10 1	2 39
21.	17 55	— 23 52	5 18	9 54	2 30
31.	18 27	— 23 51	5 9	9 46	2 23

JUPITER.

Jan. 1.	8 38	+ 19 7	6 48 P.M.	1 58 A.M.	9 8 A.M.
11.	8 34	+ 19 27	6 2	1 13	8 24
21.	8 28	+ 19 47	5 16	12 29	7 42
31.	8 23	+ 20 7	4 26	11 40 P.M.	6 54

SATURN.

Jan. 1.	14 59	— 14 39	3 4 A.M.	8 17 A.M.	1 30 P.M.
11.	15 2	— 14 51	2 28	7 41	12 54
21.	15 5	— 15 0	1 53	7 4	12 15
31.	15 7	— 15 7	1 16	6 27	11 38 A.M.

URANUS.

Jan. 1.	15 23	— 18 16	3 41 A.M.	8 41 A.M.	1 41 P.M.
11.	15 25	— 18 23	3 4	8 3	1 2
21.	15 26	— 18 28	2 28	7 26	12 24
31.	15 27	— 18 33	1 49	6 47	11 45 A.M.

[illegible] of the

NEPTUNE.

[illegible]	Rises. H. M.	Transits. H. M.	Sets. H. M.
[illegible]	[illegible] 57 P.M.	10 16 P.M.	5 35 A.M.
[illegible]	[illegible] 16	9 35	4 54
[illegible]	[illegible] 36	8 55	4 14
[illegible]	[illegible] 56	8 15	3 34

[illegible] SATELLITES, P. S. T.

[illegible] January 24th, the phenomena are to be [illegible] the planet, a little below the line of the [illegible] telescope. After opposition, the [illegible] limb.

			H. M.
[illegible] M.	I, D, Jan.	15.	3 54 P. M.
[illegible] M.	II, D,	16.	1 11 A. M.
[illegible] M.	I, D,	19.	4 51 A. M.
[illegible] M.	IV, D,	20.	5 42 P. M.
[illegible] M.	I, D,	20.	11 20 P. M.
[illegible] M.	III, D,	22.	4 15 A. M.
[illegible] M.	I, D,	22.	5 48 P. M.
[illegible] P. M.	II, R,	26.	7 55 P. M.
[illegible] P. M.	I, R,	28.	3 30 A. M.
[illegible] M.	I, R,	29.	9 58 P. M.
[illegible] P. M.	I, R,	31.	4 27 P. M.
[illegible] M.			

FEBRUARY, 1896.

[illegible] two during the month, and neither of [illegible] United States.

[illegible] *the Sun* occurs on February 13th, visible [illegible] the south pole. The eclipse will be [illegible] coast of South America and the west [illegible]

[illegible] *Moon* on February 28th, visible in the [illegible] greatest magnitude is eighty-seven per [illegible] diameter.

Ja

[illegible] star at the beginning of the month, but [illegible] Sun, coming to inferior conjunction on [illegible] rapidly recedes from the Sun, and, by [illegible] ly at greatest western elongation [illegible] little more than an hour before [illegible] sunrise, and may possibly be seen if the weather conditions are good.

Venus is still a morning star, but is drawing nearer the Sun and rising later. It moves through the constellation *Sagittarius* into *Capricorn.*

Mars is also a morning star, rising about two hours before the Sun. It is moving eastward in the same part of the heavens as *Venus*, the latter moving much more rapidly, and passing from a position about four degrees west on February 1st to a position about ten degrees east on February 29th. On February 9th, *Venus* passes one degree thirty-eight minutes north of *Mars.*

Jupiter rises before sunset on February 1st, and remains above the horizon practically the entire night. At the end of the month it sets at a little before 5 A. M. It retrogrades about three degrees in the constellation *Cancer*, and is a little west of the "Bee-hive" cluster.

Saturn, by the end of the month, rises shortly after 11 P. M. It moves a little eastward until February 26th, when it turns and begins to move westward in the eastern part of the constellation *Libra.*

Uranus follows after *Saturn*, rising just before midnight on February 29th. It is near the boundary line of *Libra* and *Scorpio.*

Neptune is nearly stationary in the eastern part of the constellation *Taurus.*

PHASES OF THE MOON, P. S. T.

		H. M.
Last Quarter,	Feb. 5,	4 38 P. M.
New Moon,	Feb. 13,	8 13 A. M.
First Quarter,	Feb. 21,	1 15 P. M.
Full Moon,	Feb. 28,	11 51 A. M.

THE SUN.

1896.	R. A. H. M.	Declination. ° ′	Rises. H. M.	Transits. H. M.	Sets. H. M.
Feb. 1.	20 59	— 17 9	7 11 A.M.	12 14 P.M.	5 17 P.M.
11.	21 39	— 14 5	6 59	12 14	5 29
21.	22 18	— 10 37	6 47	12 14	5 41
Mar. 2.	22 55	— 6 53	6 33	12 12	5 51

Mercury.

1896.	R. A. H. M.	Declination. ° ′	Rises. H. M.	Transits. H. M.	Sets. H. M.
Feb. 1.	21 49	— 10 51	7 37 A.M.	1 4 P.M.	6 31 P.M.
11.	21 11	— 12 26	6 26	11 47 A.M.	5 8
21.	20 50	— 15 34	5 37	10 46	3 55
Mar. 2.	21 11	— 16 11	5 22	10 28	3 34

Venus.

Feb. 1.	18 14	— 21 59	4 45 A.M.	9 29 A.M.	2 13 P.M.
11.	19 6	— 21 42	4 59	9 42	2 25
21.	19 58	— 20 22	5 4	9 54	2 44
Mar. 2.	20 48	— 18 3	5 5	10 5	3 5

Mars.

Feb. 1.	18 30	— 23 49	5 9 A.M.	9 46 A.M.	2 23 P.M.
11.	19 3	— 23 21	5 0	9 39	2 18
21.	19 35	— 22 28	4 49	9 31	2 13
Mar. 2.	20 7	— 21 12	4 37	9 24	2 11

Jupiter.

Feb. 1.	8 22	+ 20 9	4 21 P.M.	11 35 P.M.	6 49 A.M.
11.	8 17	+ 20 27	3 36	10 51	6 6
21.	8 12	+ 20 42	2 50	10 7	5 24
Mar. 2.	8 9	+ 20 53	2 07	9 24	4 41

Saturn.

Feb. 1.	15 7	— 15 7	1 12 A.M.	6 23 A.M.	11 34 A.M.
11.	15 8	— 15 11	12 35	5 45	10 55
21.	15 9	— 15 12	11 57 P.M.	5 7	10 17
Mar. 2.	15 9	— 15 10	11 17	4 27	9 37

Uranus.

Feb. 1.	15 28	— 18 33	1 46 A.M.	6 44 A.M.	11 42 A.M.
11.	15 28	— 18 36	1 7	6 5	11 3
21.	15 29	— 18 37	12 29	5 26	10 23
Mar. 2.	15 29	— 18 37	11 50 P.M.	4 47	9 44

Neptune.

1896.	R. A. H. M.	Declination. ° '	Rises. H. M.	Transits. H. M.	Sets. H. M.
Feb. 1.	4 57	+21 12	12 52 P.M.	8 11 P.M.	3 30 A.M.
11.	4 57	+21 12	12 12	7 31	2 50
21.	4 57	+21 12	11 33 A.M.	6 52	2 11
Mar. 2.	4 57	+21 13	10 54	6 13	1 32

Eclipses of *Jupiter's* Satellites, P. S. T.

The eclipses are to be seen near the right limb of the planet, a little below the line of the belts, as seen in an inverting telescope.

	H. M.		H. M.
II, R, Feb. 2.	10 30 P. M.	I, R, Feb. 16.	2 45 P. M.
I, R, 4.	5 24 A. M.	II, R, 17.	3 41 A. M.
III, R, 5.	3 42 P. M.	III, R, 19.	11 42 P. M.
I, R, 5.	11 53 P. M.	I, R, 20.	3 42 A. M.
IV, R, 6.	4 17 P. M.	II, R, 20.	4 59 P. M.
I, R, 7.	6 21 P. M.	I, R, 21.	10 11 P. M.
II, R, 10.	1 6 A. M.	I, R, 23.	4 40 P. M.
III, R, 12.	7 42 P. M.	III, R, 27.	3 42 A. M.
I, R, 13.	1 47 A. M.	II, R, 27.	7 34 P. M.
I, R, 14.	8 16 P. M.	I, R, 29.	12 6 A. M.

HELIUM, ASTRONOMICALLY CONSIDERED.

By Edwin B. Frost.

Scientific discoveries seldom come singly. The mastering of one problem of nature commonly suggests new modes of attacking other problems, and often contains in itself the key to their solution. Perhaps it is quite as frequently the case that new discoveries follow incidentally, it may be, in the researches for completing the original discovery, or in the revived interest in subjects previously supposed to be exhausted for research with known methods.

So it was that the brilliant discovery in 1894, by Lord Rayleigh and Professor Ramsay of the gaseous element, argon, after very long and painstaking researches, led incidentally to the detection of terrestrial helium by the latter of these distinguished investigators—a discovery of far more astronomical importance than that of argon itself. The renewed interest in the study of gases occluded in minerals may very possibly soon bring to light still other elements.

In a paper sent to the Royal Society on March 26, 1895, and read a month later, Professor RAMSAY recites the circumstances leading to the discovery of the missing element, helium, so well known as a constituent of the Sun and certain stars, but hitherto not isolated on the Earth. We quote from that paper:* "In the course of investigations on argon, some clew was sought for, which would lead to the selection of one out of the almost innumerable compounds with which chemists are acquainted, with which to attempt to induce argon to combine. A paper by W. F. HILLEBRAND, 'On the Occurrence of Nitrogen in Uraninite, etc.' (*Bull. of the U. S. Geological Survey*, No. 78, p. 43), to which Mr. MIERS kindly directed my attention, gave the desired clew. In spite of HILLEBRAND'S positive proof that the gas he obtained by boiling various samples of uraninite with weak sulphuric acid was nitrogen (p. 55)—such as formation of ammonia on sparking with hydrogen, analysis of the platinichloride, vacuum-tube spectrum, etc.,—I was skeptical enough to doubt that any compound of nitrogen, when boiled with acid, would yield free nitrogen. The result has justified the skepticism.

"The mineral employed was clèveite, essentially a uranate of lead, containing rare earths. On boiling with weak sulphuric acid, a considerable quantity of gas was evolved. It was sparked with oxygen over soda, so as to free it from nitrogen and all known gaseous bodies, except argon; there was but little contraction; the nitrogen removed may well have been introduced from air during this preliminary experiment. The gas was transferred over mercury, and the oxygen absorbed by potassium pyrogallate; the gas was removed, washed with a trace of boiled water, and dried by admitting a little sulphuric acid into the tube containing it, which stood over mercury. The total amount was some twenty cubic centimetres.

"Several vacuum-tubes were filled with this gas, and the spectrum was examined, the spectrum of argon being thrown simultaneously into the spectroscope. It was at once evident that a new gas was present along with argon.

"Fortunately, the argon-tube was one which had been made to try whether magnesium-poles would free the argon from all traces of nitrogen. This it did; but hydrogen was evolved from the magnesium, so that its spectrum was distinctly visible. Moreover, magnesium usually contains sodium, and the *D* line was also visible, though faintly, in the argon-tube. The gas from clèveite also showed hydrogen lines dimly, probably through not having been filled with completely dried gas.

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* *Proc. R. S.*, Vol. LVIII, 65-67, 1895; reprinted in *Nature*, Vol. LII, 7-8.

"On comparing the two spectra, I noticed at once that while the hydrogen and argon lines in both tubes accurately coincided, a brilliant line in the yellow, in the clèveite gas, was nearly, ***but not quite***, coincident with the sodium line *D* of the argon-tube.

Mr. CROOKES was so kind as to measure the wave-length of this remarkably brilliant yellow line. It is 587.49 millionths of a millimeter, and is exactly coincident with the line D_3 in the solar chromosphere, attributed to the solar element which has been named *helium.*"

The paper gave a further comparison between the spectrum of the argon-tube and the helium-tube, but, as later appeared, the presence of the argon lines in the helium-tube must have been due to the accidental introduction of air.

In the same number of the *Proceedings*, a note by Professor LOCKYER follows, in which he describes* the results he obtained, immediately after hearing of the discovery, by the process of heating *in vacuo* particles of uraninite, and photographing the spectrum of the resulting gas. A number of lines now known to have been due to impurities were thus registered, but the spectrum showed the chromospheric line at λ 4472, which, as LOCKYER stated, is "as important as D_3 itself, from the theoretical point of view, to students of solar physics."

Meanwhile, the spectrum of the new gas was being studied by numerous other spectroscopists, and CLÈVE published† THALEN'S visual but accurate measures of the wave-lengths of six lines, all well known in the solar chromosphere, namely: λ 6677, D_3, 5048, 5016, 4922, 4714. At the session of the Royal Society, on May 9th, two notes were presented by LOCKYER, in which he described the results of his experiments upon a number of minerals of the class of uraninite. From the variations in the occurrence and intensities of the different lines, both in the chromosphere and in the laboratory, LOCKYER considered the evidence to be strong that helium is a mixture, not a single element. A list was given of seventeen lines measured on photographs (from λ 3889 to λ 4580) of the spectra from eighteen minerals. Of these, all but five (those at λ 3889, 4026, 4144, 4389, 4471) now seem to have been due to impurities which could not well be avoided in the distillation method used.

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* Also, in *Nature*, Vol. LII, 8, 1895.

† *C. R.*, Vol. CXX, 834-835, (April 16th).

At the *séance* of the French Academy on May 20th, DESLANDRES communicated* the well-determined wave-lengths of twenty lines, including eleven of those already named, all of which have since been fully confirmed as belonging to the pure spectrum of helium. He also showed the numerous coincidences of these lines with those of the chromosphere, and cites the difference in their intensities in the chromosphere as evidence that what is called helium is a mixture or compound.

Thus far, however, the wave-length of the orange line had not been determined with the utmost accuracy that modern apparatus permits, and, doubtless, some skepticism still prevailed as to the absolute coincidence with D_3. The crucial test soon came, however, in a letter from Prof. RUNGE, dated at Hanover on May 16th, and published in *Nature* (Vol. LII, 128,) on June 6th. With Prof. PASCHEN, he photographed the concave-grating spectrum of clèveite, with iron for comparison, and found the orange line a *double*, a strong component at λ 5875.883, and a weak comparison at λ 5876.206 (ROWLAND'S standard value, without any mention of duplicity, being 5875.982). RUNGE, therefore, dissented from the conclusion that the line coincided with D_3, "*unless D_3 is shown to be double.*" This brought out a letter from Dr. HUGGINS (*Chem. News*, Vol. LXXI, 283, June 14, 1895,) affirming his conviction, based on earlier observations as well as special ones for the purpose, that the chromospheric D_3 is not double. He recalled that BELOPOLSKY (*Mem. Societá Spett. Ital.*, May, 1894,) had occasionally seen D_3 apparently rendered a double by the superposition of terrestrial lines, and raised the query: "May it be that the clèveite gas is the stuff giving rise to these terrestrial lines?" HALE,† however, obtained the opposite result; for, directly upon reading RUNGE'S note, he observed D_3 in the fourth order grating-spectrum of a very bright prominence, which luckily was on the limb at the time. A faint companion was at once detected on the less refrangible side of

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* *C. R.*, Vol. CXX, 1112–1114.

† *Astrophysical Journal*, Vol. II, 165–166.

D_3, at a distance which he measured (on June 20th and 21st) as 0.357 tenth-meters, a result differing by only 0.034 tenth-meters from that of RUNGE and PASCHEN. The duplicity of D_3 was soon confirmed by various possessors of powerful spectroscopes, and Dr. HUGGINS observed it a few weeks later under more favorable atmospheric conditions. The proof of the identity of D_3 was thus practically complete.

Additional lines of the spectrum of clèveite and other minerals were rapidly announced,—the important unidentified chromospheric line at λ 7065 by LOCKYER,* and another line in the red, at λ 7285 (more accurately 7282), by DESLANDRES.† Finally RUNGE and PASCHEN communicated,‡ July 11, to the Berlin Academy the results of their very accurate determinations of wave-lengths of lines in the spectrum of GEISSLER tubes containing gas extracted from a pure crystal of clèveite. They were able to explore the ultra-red spectrum with a bolometer, and there discovered two lines which they had been led to expect from theoretical reasons,—the rhythmical relations of the wave-lengths.

It is now ten years since BALMER announced that the wave-lengths of the lines of the principal series in the hydrogen spectrum can be expressed by the formula

$$\lambda = \lambda_0 \frac{m^2}{m^2 - 4}$$

where λ_0 is a constant wave-length, and m has successively the values 3, 4, 5, etc. Somewhat similar formulæ have been found by other investigators for numerous elements. The formula applying to helium was found by RUNGE and PASCHEN to be

$$\frac{1}{\lambda} = A - \frac{B}{m^2} - \frac{C}{m^4},$$

where A, B and C are constants. As they state: "A determines the end of the series toward which the lines approach for high values of m, but does not influence the difference of the wave-numbers of any two lines. B has nearly the same value for all the series observed, and C may be said to determine the spread of the series, corresponding intervals between the wave-numbers being larger for larger values of C. As B is approximately known, two wave-lengths of a series suffice to determine the constants *A* and *C*, and thus to calculate approximately the wave-lengths of the other lines. It was by this means that we succeeded in disentangling the spectrum of the gas in clèveite, and showing its regularity." As a result of their analysis they find six series of lines in the spectrum of the gas from clèveite, and they assign three series to each of what they call "constituents" of helium, their reasoning leading them to the conclusion that the gas is a mixture of two distinct elementary gases. The wave-lengths are as follows, two of the series being chiefly composed of double lines :

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* *Proc. R. S.*, Vol. LVIII, 192, dated May 28, 1895.

† *C. R.*, Vol. CXX, 1331-1333, June 17.

‡ Reprinted in *Phil. Mag.* Vol, XL, 297-302, September 1895.

HEAVIER CONSTITUENT (HELIUM PROPER).			LIGHTER CONSTITUENT.		
PRINCIPAL SERIES.	FIRST SUBORDINATE SERIES.	SECOND SUBORDINATE SERIES.	PRINCIPAL SERIES.	FIRST SUBORDINATE SERIES.	SECOND SUBORDINATE SERIES.
11220.			20400.		
3888.97	5876.206	7065.77	5015.73	6678.1	7281.8
3888.76	5875.883	7065.51	3965.08	4922.08	5047.82
3187.98	4471.85	4713.39	3964.84	4388.11	4437.73
3187.83	4471.66	4713.17	3613.89	4143.91	4169.12
2945.35	4026.52	4121.15	3613.78	4009.	4024.14
2945.22	4026.35	4120.98	3447.73	3927.	3936.1
2829.32	3819.89	3867.77	3354.7	3872.	3878.3
2829.16	3819.75	3867.61	3296.9	3834.	3838.2
2764.01	3705.29	3733.15	3258.3	3806.	3808.3 (?)
2763.91	3705.15	3733.01	3231.3	3785.	
2723.3	3634.52	3652.29	3213.4		
2696.5	3634.39	3652.15			
2677.1	3587.54	3599.			
	3587.42	3563.			
	3554.5	3537.			
	3530.6	3517.			
	3512.6	3503.			
	3498.7	3491.			
	3487.8	3482.			
	3479.2				
	3472.				
	3466.				
	3461.				

Nature for August 29th (Vol. LII, 428–430) reprints from the *Chemical News* of the preceding week an article by CROOKES, giving the wave-lengths of all the lines measured by him in the spectra of five samples of gas from different mineral sources. The lines include nearly all those given by RUNGE and PASCHEN, and a large number in addition, which would seem to be due to some other substance or substances contained in the minerals. Some of these lines have also been observed by LOCKYER, and may have an astronomical importance when their origin is more accurately located. In view of the different, and even antithetical, behavior of spectral lines of the same element under different conditions of electric tension, temperature, pressure, etc., opinion may for the present be reserved as to the correctness of the conclusion of RUNGE and PASCHEN regarding the compound character of helium, but it certainly would seem that the two spectra must correspond to two quite definite physical states of the radiating gas, if it be elementary. It will be recalled that argon gives two quite distinct spectra ; but the harmonic relations of argon lines have apparently not yet been investigated. In passing, it may be stated that as yet argon has no astronomical significance, as no lines of its spectrum have thus far been recorded in celestial spectra. According to the latest statement seen by the writer, RAMSAY does not, from the chemical point of view, accept the conclusion that helium has two constituents. With a proper reserve, however, it is for the present quite allowable to use the terms heavier and lighter constituent.

Helium (both constituents) has recently been detected as bubbling from certain springs in the Black Forest, in the Pyrenees, and elsewhere; so it must be more or less present with argon in the atmosphere. KAYSER considers that the faint helium lines seen by him in the spectrum of argon that had been prepared as carefully as possible are direct proof of its presence in the atmosphere at Bonn.

The density of helium has been found by CLÈVE to be 2.02, by RAMSAY to be 2.18, in terms of the density of hydrogen. It has not yet been possible to induce helium to enter into combination with other elements.

We have already alluded to the coincidences of the new helium lines with well-known chromospheric lines whose indentification had hitherto been doubtful, — especially, of course, λ7066, D_3, and LORENZONI'S *f*, (which is the strong line at λ4472), all of which are permanently present in the chromospheric spectrum. A large number of the ultra-violet chromospheric and prominence lines photographed by HALE and DESLANDRES are also doubtless coincident with helium lines. The singular fact that none of the helium lines are present as dark lines in the Sun, wherein the new lines only follow the example of D_3, still awaits a satisfactory explanation. It had formerly been inferred that D_3 did not occur as a dark line in any celestial spectrum, but dark D_3 was not long ago detected at the Lick Observatory, in β *Lyræ* by Keeler, and in β and ε *Orionis* by Campbell.

In the spectra of the nebulæ helium is conspicuous, but the lines of the "heavier constituent" are far the more prominent—in a measure a confirmation of the correctness of the differentiation of the constituents. D_3 was discovered in the *Orion* nebula by Copeland in 1886, and a faint line at λ 4476 in the following year. D_3 has since been observed by Keeler and by Campbell in other nebulæ, and the latter has measured λ 4472 in several nebulæ. Every one of the lines of "helium proper" occurring within the limits of the known nebular spectrum up to λ 3700 can be readily identified with some line in the latter, while of the nineteen lines within these limits, assigned to the "lighter constituent," but six (those at λ 4923, 4388, 4169, 4144, 4009, and 3878) have been certainly recorded in nebulæ.

Our knowledge of stellar spectra of Type Ia does not seem to be especially affected by the discovery of terrestrial helium, as the dark lines of helium are not ordinarily visible in this type. However, the 4472 line has been photographed by Scheiner in the spectra of the *Orion* stars δ, γ, and ζ, which are included in Class Ia, and α *Virginis*, *Algol*, η *Ursæ majoris*, and β *Tauri;* and λ 4388 (of the lighter constituent) is found in α *Virginis* and γ *Orionis*. Yet it is not to be inferred that helium may not be present in stars of this class, as also in stars at the solar stage (Class IIa), in which no lines of helium have yet been recorded. If we were only able to study the spectrum of the Sun as a whole, without examining the separate spectrum of the limb, we should not know that solar helium existed.

With spectra of Type Ib, however, the conditions are quite different from those of the two types just considered. Here the characteristic dark line, often called the "Orion line" from its occurrence in stars of *Orion* near the nebula, is at once located, after long baffling identification, as the strong helium line at λ 4472, which appears as a bright line in the nebula. This is quite in accord with the recent observations of dark D_3 in certain *Orion* stars of this class (in β, Campbell, Keeler; in ε, Campbell; in γ and ζ, Fowler), although it had already been surmised that the substance producing the "Orion line" must be of a somewhat similar character to hydrogen. Of about fifty lines given by Keeler and by Scheiner in the spectrum of β *Orionis*, some eleven are due to helium, both "constituents" being represented. A close physical connection is indicated between these stars of *Orion* and the great nebula, although the latest observations of CAMPBELL and KEELER do not confirm HUGGINS' photograph of bright lines in the spectra of the trapezium stars, as they are dark on their plates.

In stars of Class Ic, including *β Lyræ*, γ *Casșiopeiæ*, and *P Cygni*, helium predominates, its lines being more numerous in *β Lyræ* than even those of hydrogen. These two elements together characterize this star, and produce most remarkable shifting bands, with bright and dark components. The extraordinary complexity of the band in *β Lyræ* near hydrogen ζ (λ 3889) is at once explained as the result of the juxtaposition and probable overlapping of the two bands, one due to hydrogen and the other to helium. Orbital motions are evident in *β Lyræ*, and possibly occur in other stars of this class, which adds to their interest as being objects apparently in one of the earliest stage of development from the nebulæ.

As has been already said, helium lines have not been observed in spectra of the solar type, which only confirms the view that those stars are in almost the identical condition of our Sun.

It seems singular, however, that the WOLF-RAYET stars, of Class IIb, should not show helium more conspicuously. These stars have recently been very successfully studied by CAMPBELL, but of over fifty lines measured only four can be assigned to helium, namely: D_3, λ 4472, 4388, and 4026. The identification of most of the lines of these spectra must await further discoveries of terrestrial chemistry.

Laboratory helium adds something, however, to our knowledge of temporary stars; for quite a number of the important lines of *Nova Aurigæ* can now be assigned to it. Especially noteworthy is the strong line in the green, at λ 5016, whose wavelength was carefully determined by numerous observers. This is undoubtedly identical with the second line of the first series of the lighter constituent at λ 5015.7, and hence the idea of some must be abandoned that the line was really the chief nebular line (λ 5007) greatly displaced. Both helium constituents were present in the *Nova*, but the lighter was the more conspicuous. It is, however, quite remarkable that at the second apparition, when the spectrum had become nebular, only three of the helium lines were present, all very faint, although, as has already been stated, helium lines are abundant in the brighter nebulæ.

Helium does not manifest itself in stars of Classes IIIa and IIIb, as indeed could hardly be expected; for, with the increased absorption by the compounds which seem to form at the presumably low temperature of these stars, hydrogen and the lighter gases appear to retire. Helium lines might be looked for among the bright lines that flash out as the long-period variables of Class IIIa approach a maximum, but they do not seem to be present. Comets, meteors, and aurora alike give no spectroscopic testimony of helium, although its presence has been chemically detected by RAMSAY in a meteorite. With this ends the present record of helium as a constituent of celestial objects. First discovered in the Sun, it has eluded detection in our own planet for over a quarter of a century, but the logic of common origin and common chemical constitution of Sun and Earth has now been vindicated.

It is not too much to expect that the revived study of gases occluded in minerals will soon lead to the discovery of other substances or elements whose existence is thus far known to us only from the spectroscopic evidence of celestial objects. In particular, we ought next to hope for the enrollment among the family of terrestrial elements of the substances producing the corona line and the characteristic nebular lines.

DARTMOUTH COLLEGE, HANOVER, N. H., Nov. 18, 1895.

THE MOON,* BY THOMAS GWYN ELGER.

REVIEWED BY M. C. M. GAUDIBERT.

Since M. WEBB, many years ago, published in his well-known and highly appreciated book, *Celestial Objects for Common Telescopes*, his short but very suggestive treatise on the Moon, the study of the visible surface of our satellite has received such an impetus among an ever-increasing number of observers, that no slackness is perceptible even to the present day. This little work, also, came out about the time when MM. G. WITH and BROWNING placed in the hands of the public their deservedly celebrated telescopes with silvered mirrors, at such comparatively low price that almost every one who had a taste for astronomy could gratify their desire and survey the sky, gazing on the myriads of worlds as far as their instruments could reach. The Moon, of course, was the globe which most arrested the attention of amateurs; and it was soon found that it was not an exhausted world, but that there was much more to discover on its surface than professional astronomers generally had suspected.

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* The Moon, a full description and map of its principal physical features, by THOMAS GWYN ELGER, F. R. A. S. London, GEORGE PHILIP & SON, 1895. 8vo, pp. 173.

At that time, WEBB's little book and the map of the Moon it contains were almost the only guide and unique source of information within the reach of an eager and continually increasing number of observers. The clear and precise descriptions M. WEBB gave of a large number of lunar formations, instead of satisfying the requirements of the possessors of the new silvered telescopes, increased, on the contrary, their eagerness to know more. It was then that the *English Mechanic* became the recipient of a multitude of observations and discoveries made by observers, and through its means selenography made such progress that it can be well compared with the progress it has made since *Societies* have officially taken charge of it. During this period the name of M. BIRT impresses itself on the memory, and one gratefully remembers his services to selenography, and his devotedness in helping observers and directing their efforts.

When M. NEISON's book on the Moon was published, it soon found its way into the libraries of public and private observatories, and also in the hands of many observers. It is not my purpose here to speak of the high value of this book, of which I have not the least doubt. I wish only to point out what I consider to be two defects which, I feel convinced, have been felt by many. The first is that, for amateurs generally, the book is too bulky, and, therefore, not easy to handle at the telescope; the maps themselves, as they are disposed, adding not a little to the difficulty. The second is its high price, which places it beyond the reach of many who, having spent as much as they conveniently could for a telescope, are obliged to deprive themselves of the help they might have received from this book had it been less expensive.

The Moon, by M. ELGER, happily fills up that gap. This cheap and handy volume, I am convinced, will soon be in the hands of every observer who, up to the present time, has had no guide to help and lead him in the fascinating studies of our satellite; and those, even, who are already provided with other means, will not read this work without profit.

It is not to be expected that the reader will find in this book as many details as in the more expensive work of NEISON. But whatever is essential in the last will be found in the first, and besides, many considerations which are the results of more recent studies, and even several discoveries hitherto unknown. M. ELGER is not a tyro. He has had more than thirty years' experience in selenographical observations with two good instruments. He cannot but be a safe guide, and, so far as he goes, the student may have full confidence in his teaching. He might, perhaps, have gone somewhat further, now that lunar photography has opened up before us such bright prospects, anticipating in this way what circumstances, not far distant, I feel certain, will oblige every writer on the Moon to take into account, and to give to it a prominent place.

The Moon, by M. ELGER, is composed of an introduction, a catalogue of lunar formations, and an index, with a lunar map. The introduction is not only interesting, but also very important. It contains a short notice of selenographers since the "earliest times" down to the present day, showing the part played by the principal philosophers and selenographers in the gradual development of that branch of astronomy. Then M. ELGER defines the various formations the observer will meet with. These definitions are of the first importance, and the beginners, especially, will do well to get thoroughly acquainted with them, as they will be of the greatest use when they observe through the telescope, and also when they are called to describe what they see. They will find that these definitions are not dry, logical abstractions, but, on the contrary, descriptions of objects to which they refer, with a large amount of details and examples to which those definitions apply. When the student has well mastered the contents of this introduction, he will be well prepared to make the best use of the second part of this valuable book, which consists of a catalogue of 501 objects. Each of these objects is discussed in clear and precise terms, but, of course, with more or less details, according to their importance and the degree of knowledge we have attained up to the present time. It will be found that not only the principal objects are thus described, but also secondary formations as well as peaks on the walls and principal mountains in the neighborhood.

The map is part and parcel of the book, and, as it is divided into four quadrants, each quadrant is placed at that page of the book where the description of the objects it contains begins. I believe no better mode could be found to render its use handy and pleasant. It is also clearly printed, and no great difficulty will be found, even with a dim light, in distinguishing every object it contains.

In the appendix will be found the description of the map, a list of the Maria, or gray plains, termed seas, a list of some of the most prominent mountain ranges, promontories, isolated mountains, and remarkable hills; also a list of the principal ray-systems, light-surrounded craters, and light spots; the position of the terminator, contained in two most useful tables extending to the end of the present century; the lunar elements, and, lastly, an alphabetical list of formations.

It will thus be seen that a most useful and handy book on selenography is now within the reach of every student of the satellite of the Earth, and, for my part, I wish it good speed.

C. M. GAUDIBERT.

VAISON, VAUCLUSE, FRANCE.

(NINETEENTH) AWARD OF THE DONAHOE COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to Dr. LEWIS SWIFT, Lowe Observatory, California, for his discovery of an unexpected comet on August 20, 1895.

The Committee on the Comet-Medal,
EDWARD S. HOLDEN,
J. M. SCHAEBERLE,
W. J. HUSSEY.

October 20, 1895.

DIVISION ERRORS OF THE REPSOLD MERIDIAN CIRCLE.

By R. H. Tucker.

The determination of the errors of graduation of a divided circle offers one of the most refined problems in practical astronomy.

Notwithstanding the excellence of modern workmanship in the construction of such circles, it may be assumed that there will always remain errors, systematic or accidental, or both, in the position of the divisions.

Whether these are large enough to be a matter of concern depends not only upon the care and exactness with which the circle has been divided, but upon the accuracy aimed at in the determinations for which it is to be used.

For field instruments, it may in general be taken for granted that the errors left by any first-class maker are within the limits required in the use of the circles.

The best meridian circles now made, with the advantages which the constructors have gained from their own experience, and from the tests and investigation of circles actually in use, have probably very small outstanding errors. Still, it is important to ascertain, for any particular instrument, what degree of fineness has been reached, and to show what the probable inaccuracy of a determination, for instance, of a star's position will be, due to this source of error. The definite determination of every division of the circle would then give the means of freeing observation nearly completely from the effect of this error; not entirely, for the determination itself will necessarily have its residual of error, which should, however, be small in comparison with errors to be measured.

In observing practice it has sometimes been the custom to use a circle movable upon its axis, and to shift from time to time, so that for the various observations of any star different sets of divisions will have been employed, and the mean result will be affected by the mean of the errors of such divisions.

By observing with the circle fixed in respect to the telescope, but reversing the whole instrument, we obtain two distinct sets for the determinations of a star; or four, if each observation is made upon the pair of divisions nearest the reference point in each reading microscope.

While reversal of the instrument is intended for control and elimination of other sources of error, it has the effect of reducing in the mean result the error due to inaccurate divisions. By comparison of results of observation, knowing the probable error of circle reading, bisection, and from other sources, it is possible to arrive at an approximate estimate of the effect of division error. But it will be far more satisfactory in any discussion of work of high standard to be able to account for every source of error by independent investigation, and to show that the resulting probable error can be traced definitely to all sources.

The investigation only of a sufficiently large number of graduations to show the effect of division error upon the observation of star places will at least give definite data; while, as the process must consist, in the main, of a series of steps, each depending upon those preceding, whatever is done affords a basis for continuation. The present plan for the REPSOLD meridian circle includes the investigation of every degree of the fixed circle, which is the one ordinarily employed in observation. The problem in full is to determine the exact angle between any two divisions marking the degrees. For this purpose, any particular division may be adopted as the reference mark, and the angles of the others are then to be measured from it. Two divisions, 180° apart, may be taken as a standard diameter, and the angles to other diameters may be measured; or the mean of two diameters at right angles giving a set of four divisions ninety degrees apart, may be adopted, and all other sets of four be referred to them.

If it is the custom to read the circle by all four of the microscropes, the last solution will give the data needed. This is the plan of the present undertaking; but the material thus accumulated affords all that is necessary for the determination of each separate division of the four. The readings would need to be corrected for eccentricity and flexure, and the positions and changes in the individual microscopes followed up.

There are two methods for the determination of division error, either of which may be employed with this instrument. One may use simultaneous readings of the two circles, for investigations of the errors of one or both.

Or, by a pair of extra microscopes, which may be set at any angle desired with respect to the four ordinarily used, the errors of one circle may be investigated.

The first process has been the one employed thus far; while, in further work, the other may be adopted. Before outlining the process of observing, some account of the instrument should be given. The circles are two feet in diameter, each being divided to every 2′, there being about 150 divisions to the inch. This affords an idea of the scale; an arc of 1″ upon the circle is represented in lineal measure by $\frac{1}{18000}$ inch.

The circles are read by microscopes of twenty-six inches focal length, having an effective magnifying power of thirty-five diameters. Each microscope screw carries a pair of threads about 25″ apart, the screw-heads being divided into sixty parts, affording easy estimates of tenths, or very closely 0″.1.

The circles are graduated in the same direction, increasing opposite to the hands of a watch as one faces the circle. One of them is movable upon its axis, permitting of easy and quick adjustment in any position with respect to the other, or fixed, circle.

The general outline of observing is then to apply successively the arcs of one circle, as a measure to similar arcs of the other. By the application, for instance, of all arcs of 3° in length of one circle, to all arcs of 3° upon the other, the errors in the length of each arc of both circles is determined. And for either circle the errors of its 3° arcs are entirely independent of the errors of the other circle.

This can perhaps be made plain by an illustration.

(*a*) If we had an exact yard-stick, and wished to measure an exact foot, if we divided the yard into three approximately equal parts, and applied each of them in succession, the mean of the three measures would be an exact foot. The parts, of course, except for convenience, we will say, in making the measurement, need not even be approximately of the same length; their sum will be a yard, and the mean one foot.

(*b*) The resulting exact foot could then be used to mark off three equal divisions upon the yard-stick.

The problem then resolves itself into that of making our comparisons as accurately as possible. Our exact standard is the entire circumference of either circle, by which the aliquot parts of the other are to be measured.

It will be clear that no assumption is made of errors balancing in their effect; nor that the average of any number of division errors, however large, will be zero.

The process, on the contrary, gives, within the error of observation, the difference in angle between any two of the degree marks, upon the circle fully measured.

By reading the two circles simultaneously in one position, and then moving the telescope, carrying them both through any angle to another position, the difference of the two measures of the angle will be due to a combination of the following causes:

First.—Personal error in each reading. As far as personal equation is concerned, this should have no effect, since, with constant illumination and no variable conditions, it should affect all readings alike.

There remains the accidental inaccuracy, or probable error, to which every observation of every character is subject, to a varying degree. It can never be eliminated; but an increasing accuracy can be attained up to a certain practicable limit, by increase of the number of readings.

Second.—Changes in the relation of the two circles to each other, when the position of each is changed. This may be due to the flexures of the circles, and these should consequently be determined and corrected for, if necessary; or, better, the readings can be so arranged that the effect will be eliminated. By flexure here referred to, that of a twisting character is meant. The flexure, resulting from a compression or flattening of the circles, will always be eliminated from the mean of four microscopes; just as the eccentricity of each circle, which will affect every microscope reading, in the two positions, will be eliminated in the mean of four.

The twisting effect may be due to some especial weakness of the rim, or to an unequal distribution of weight. It can be assumed to be of the same character as would be produced by attaching a small weight to the rim of a circle, which would evidently vary in its effect depending upon the position of the circle. Tests were made in the investigation of division error at the DUDLEY Observatory, to show this practically.

The circle flexure, once determined in amount, can be corrected for by means of two terms, acting respectively in proportion to the sine and cosine of the angle between any position of the circle and some adopted position. Thus, taking the position of the fixed circle when the telescope points to the zenith, the flexure correction can be determined and applied for any other position, in terms of sine and cosine Z. D. The flexures of both circles have been accordingly determined.

The effect is eliminated from the mean of two readings, in positions of the circle 180 degrees apart; and, in order to reduce all systematic corrections, with their corresponding errors, the system of reading in the two opposite positions has been carried out in the present work.

Third.—Changes may also occur in the shape of one of the circles, thus altering its relation to the microscopes; or one or more of the microscopes may change in position with respect to the others. Such changes are observed as between successive nights, and even during the course of a night's observing, and are traceable, somewhat obscurely, to changes of temperature in general.

They can be guarded against by making readings in a series, forward and back, so that the detection of change is possible by comparison. Any progressive change is also eliminated in the mean of the two readings, since the means of all made in the same positions fall at nearly the same epoch.

The series should, however, be short, and anything that would tend to produce a change should be avoided. The excellent ventilation of the meridian-circle room, and the isolation of the heat of the lamps, leave nothing to be desired in this respect. The change in temperature in the room has been almost invariably the slight fall due at the time of day when readings are generally made.

No series of readings has ever more than barely exceeded one hour, and careful test of all the series has never shown any one which gave evidence of weakness in this respect. Even if a decided progressive movement were shown, it would be safer, in practice, to observe the series again. For the object in view involves the discussion of quantities extremely small, even in comparison with the generally precise results arrived at in work with this instrument, and it is only by attention to every detail of observation and reduction that accumulation of small errors is to be avoided.

There remains, *fourth*, the graduation errors of all the divisions upon which readings were made in the two positions. Except for accidental personal error, all other sources of error can be determined, corrected for, if necessary, or mostly eliminated by proper arrangement of the observations.

For the determination of the graduation errors of the fixed circle, the movable circle is read simultaneously through a series of positions. Then the movable circle is shifted on its axis, and again a series is made. The errors of both circles are obtained by the proper combination of these readings.

Thus, for the 45° points, each circle was read at 0° and 45°, in four positions. Then the movable circle was shifted 45°; and this was repeated, in all, eight times. This gave the division error of 45° on each circle, or, rather, the difference between 0° and 45°, which will be referred to simply as the 45° division error.

The actual error of 0° is not needed; it has been assumed ″.00 for convenience. Any other value could have been assumed. It is sometimes taken large enough to produce resulting errors for the other divisions, which shall all be of the same sign.

The 45° divisions were determined in both positions of the instrument, fixed circle west, and east, for additional weight. For as error accumulates in the successive steps, it is important to have the first ones strong.

Next follows the series, in which the movable circle is shifted 15° each time; and the series consists of readings every 15° through an arc of 90°. The opposite quadrant has to be taken in a separate series, in order that none shall exceed proper length.

The next step is down to 3°. A satisfactory expedient for this step has been to shift the circle 9° at a time, and read every 9° through an arc of 90°. Three series are observed in each position, beginning, respectively, at 0°, 3°, and 6°. This gives the same strength to the determinations, by the comparison of each 3° with two 15° divisions already measured, as if the series extended only through 30° and was observed at every 3°. And for either circle, the division errors are independent of those adopted for the other circle.

It will be noted that the 15° series gives also a new determination of the 45° arcs. Similarly, the 3° series gives further determinations of the 15° arcs. But, in the reduction, these later measures have been considered as checks only, and the measures, as made, have been carried forward without change, for which there seems to be no evident need.

Thus far the form has been that given in the illustration (*a*) of the standard yard; and every 3° of both circles has been measured.

For the determination of the single or 1° divisions of the fixed circle, the illustration (*b*) seems more apt. One of the 3° arcs of B, the movable circle, will be used throughout; each of the four 1° divisions will be compared with all of the ninety divisions of A, the fixed circle. This will give a determination of these four divisions of B, which will be actually independent of the errors of A; and these four will probably be the best-known divisions upon either circle. Since their measured errors will now be applied, in obtaining the errors of A, the fixed-circle divisions will no longer be entirely independent of the errors of B. There will be, for instance, five separate determinations of each unknown 1° division of A; three will depend upon measured 3° divisions of A and B; the remaining two will also depend upon the two newly measured 1° divisions of B.

The reduction of the observations is, in general, of a simple character. But the greatest care is necessary to avoid errors, which would be quite insignificant were it not that they might accumulate. Every individual reading of a microscope has had its test scrutiny, both to show that there could be no mistake in the original observation, and to check, by its relation to the mean, the accuracy of the mean itself. Every mean of microscopes has been taken by two separate methods; and the differences of each from the mean of four has been compared for identical or opposite positions of the circle, to control any effect of change.

Whenever any list of figures has been transferred a new mean is taken, simply as a check upon the copy itself.

As regards the observing, each series stands alone, about one hour in length. The repetition of readings forward and back has always been adhered to. The settings have been made within 10″, without any stress being laid upon closer adjustment, to avoid the effect of Runs correction, and of irregularities of screws. Each determination rests upon series made in opposite quadrants, for the elimination of circle flexure from the mean.

The results of investigation of the 3° arcs of both circles, already complete, show an average division error for the mean of four microscopes of 0″.17, with no single set much exceeding 0″.5.

From this it can be predicted that the circles have probably an average division error for single divisions of about 0″.4, and that there will be no single divisions with errors much larger than 1″. Referring back to the size of the circles, the inference is that the largest error of graduation of a single division will be about $\frac{1}{18000}$ inch; while the average will be about $\frac{1}{50000}$ inch.

Nearly 4000 complete readings of each circle are to be made to carry out the investigation as now planned and well advanced towards completion.

It is anticipated that the probable error of a final determination of division error, increasing, as it necessarily does, with each step in the subdivision, will not much exceed $\pm''.05$ for the set of four 1° marks.

This would give for the probable error of the determination of single divisions about $\pm 0''.1$, corresponding to $\frac{1}{180000}$ inch on the scale of the circle.

These figures indicate the refinement of the workmanship upon the instrument. That of the determinations may be illustrated in another way. The scratches upon the silver rim, delicate as they appear to the eye, are yet about $10''$ in width, as as seen in the miscroscopes.

In the progress of this work, it is planned to measure the position of the center of that delicate line, within a probable error of the one-hundredth part of its width; and this is to be done with respect to other lines which cannot be seen in the same field of view, but must be reached by movement of the whole instrument.

For the prosecution of this work by the simultaneous reading of both circles, I have had the volunteer assistance of Professor R. G. AITKEN, which has been given in time which was his own. The exactness of the results depends upon both observers equally, and it gives me the greatest pleasure to acknowledge his efficiency and his good will.

There is possibly no class of observing more monotonous or demanding more rigorous and persistent care in small details. And the results are so long in forthcoming, also, that one lacks the spur of accomplishment by the way; for it is not until any set of subdivisions has been completely carried out that any results are definitely obtained.

The corrections for circle flexure are represented by the expressions:

Circle A : $+ ''.08 \sin (R - 315^\circ) + ''.04 \cos (R - 315^\circ)$;
Circle B : $+ ''.02 \sin (R - 315^\circ) + ''.05 \cos (R - 315^\circ)$;

when R is the reading of either circle, at the lower left hand microscope. The fixed circle A reads 315° when the telescope points to the zenith.

These flexures were determined with each circle in both positions, east and west. The corrections will need to be considered in the reduction of the readings for the horizontal flexure of the telescope, and can be combined with that correction into one term depending upon the zenith distance.

The eccentricity resulting from a discussion of the 45° arcs is $2''.61$ for circle A.

The average eccentricity for B is $1''.81$; but this will need to be combined with the eccentricity $0''.9$ of the movable circle with respect to the collar in which it turns, for any particular position.

NOTICES FROM THE LICK OBSERVATORY.

PREPARED BY MEMBERS OF THE STAFF.

GIFT TO THE LICK OBSERVATORY—THE FLOYD PHOTOGRAPHIC TELESCOPE.

Miss H. A. L. FLOYD, of Lakeport, California, has presented to the Observatory a five-inch telescope which was made by ALVAN CLARK & SONS for the private observatory of her father, the late Captain R. S. FLOYD, formerly President of the LICK Trustees. The object-glass of this instrument is so constructed that it can be used either photographically or visually. The FLOYD telescope constitutes an important addition to the equipment of the Lick Observatory. E. S. H.

October 10, 1895.

COMET *d* 1894 (BROOKS).

On November 21 at 14^h W. m. t. Mr. BROOKS, of Geneva, N. Y., discovered an unexpected comet. From LICK Observatory observations, Professor LEUSCHNER, Mr. FERRIS, and Mr. ROSS, of the University of California, have derived the following elements:

$$\begin{aligned} T &= 1895\ \text{Nov. } 21.2183,\ \text{G. m. t.} \\ \omega &= 298^\circ\ 59' \\ \Omega &= 83\ \ 1 \\ i &= 76\ \ 43 \\ q &= 0.84594 \end{aligned} \quad \left.\begin{matrix} \\ \\ \\ \end{matrix}\right\} \text{Mean Eq. 1895.}$$

This comet is under observation at Mt. Hamilton, by Professor R. G. AITKEN. E. S. H.

December 9, 1895.

SURVEY OF THE MOUNT HAMILTON RESERVATION.

By the kindness of the authorities of the U. S. Geological Survey, and especially of Mr. HENRY GANNETT, Chief of the Bureau of Topography, arrangements have been made for a survey of Mount Hamilton and vicinity. The work began in early September, and will be pushed to completion without interruption.

SONYA KOVALEVSKY.*

SONYA KOVALEVSKY, the daughter of a Russian nobleman, was born in 1850, and died in 1891. During her short life she was, in turn, the carefully guarded child of aristocratic parents, the "nihilistic wife" of a frowzy student, a student herself at the universities of Heidelberg and Berlin, a Doctor of Philosophy, with honors in mathematics, a *privat docent*, and, finally, a full professor of mathematics at the University of Stockholm. Moreover, she was the author of novels and plays which, by themselves, would have given her a high rank ; and, finally, she was the heroine of dramas played out by her own passions in her own heart, and each of these dramas was in its way a masterwork.

The book under review is a remarkable one in each of three respects, and it is interesting in a hundred others. In the first place, it gives the most vivid picture possible of the interior of one of those Russian homes of the gentry which Turgeneff and Tolstoi have painted — but no better. And it gives a lifelike image of the wave of aspiration, discontent, effort, which swept over young Russia in the years 1860–1870. The birth of the new woman of Russia is there recounted. In the second place, we have the history of the rise of a mathematical talent of a very high order. SONYA KOVALEVSKY'S name will be ranked along with the few women mathematicians — MARIA AGNESI, etc. Her talent came by descent from one of her maternal grandfathers. And, finally, her literary and dramatic successes are the record of a most remarkable life spent — and vainly spent — in *la chasse au bonheur*. Her happiness was wrecked on the rocks of a prodigious self-will.

With all these adventures and successes, her life was a melancholy failure, and she knew it to be such. Even her scientific achievements were but the masterly working out of ideas derived from her teachers. It is difficult to conceive how she could have been more cruel and unregardful of her parents and of her child. Her intense passionate desire was for two things which BALZAC strove for all his laborious years — to be famous, and to be loved. She attained both, as he did, to the uttermost. But her life ended, as it began, in wretchedness ; while his was nobly satisfied. The man had cast out selfhood ; the woman fastened the demon of self-will in her very vitals.

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* SONYA KOVALEVSKY—her recollections of childhood. Translated from the Russian by ISABEL F. HAPGOOD, etc. The Century Co., New York, 1895. 8vo.

This melancholy book, by a woman of genius, about her own development, is a document of precious value in the new questions which arise to-day. There is nothing new in the solution, but the experiment was made on noble material, with many noble aspirations, and its utter failure is all the more signal for this reason. — *Overland Monthly, October, 1895.*

A New Star in *Carina*.

From an examination of the Draper Memorial photographs, taken at the Arequipa Station of the observatory, Mrs. Fleming has discovered that a new star appeared in the constellation *Carina* in the spring of 1895. A photograph, B 13027, taken on April 14, 1895, with an exposure of sixty minutes, shows a peculiar spectrum, in which the hydrogen lines, $H\beta$, $H\gamma$, $H\delta$, $H\epsilon$, and $H\zeta$, are bright, and the last four of these are accompanied by dark lines of slightly shorter wave-length. A conspicuous dark line also appears about midway between $H\gamma$ and $H\delta$. A comparison of the spectrum of this star with that of *Nova Aurigæ* and *Nova Normæ* shows that all three closely resemble each other, and are apparently identical in their essential features. Another photograph, taken on June 15th, with an exposure of sixty minutes, shows a change in the spectrum of this object. The hydrogen lines, $H\beta$, $H\gamma$, and $H\delta$, are still bright, although the continuous spectrum is very faint. Another line, whose wave-length is about 4700, is here as bright as the hydrogen lines. On the photograph taken on April 14th it is barely visible.

An examination was next made of all the photographs of the region containing this star. On sixty-two plates, the first taken on May 17, 1889, and the last on March 5, 1895, no trace of the star is visible, although, on some of them, stars as faint as the 14th magnitude are clearly seen. The exposures of these plates varied from 10 to 242 minutes. On nine plates, the first taken on April 8th, and the last on July 1, 1895, the star appears, and its photographic brightness diminishes during that time from the 8th to the 11th magnitude. This star precedes A. G. C. 15260 (photometric magnitude 5.47) $0^m.5$, and is $1'.7$ north. Its approximate position for 1900 is, therefore, in R. A. 11^h $3^m.9$ Dec. —61° $24'$. Two stars of the 11th magnitude are near the *Nova*. One is nearly north, 110″ distant; the other is 80″ south preceding. EDWARD C. PICKERING.

October 30, 1895.
(Harvard College Observatory Circular No. 1.)

COMET *c* 1895 (PERRINE).

This comet was discovered on November 17th, at 5:30 A.M., in the constellation *Virgo*. Twilight was fast brightening, so that only pointings could be made, from which an approximate discovery position of α 13^h 44^m, $\delta + 1^\circ$ $40'$ was announced.

The comet at discovery was a bright object, having a well-defined nucleus, which was estimated at 7th magnitude, and a tail probably 10′ long. Positions were obtained for the first three mornings after discovery, from which Professor CAMPBELL computed a parabolic orbit, the elements of which are as follows:

$$
\begin{aligned}
T &= \text{Dec. } 18.4063 \\
\omega &= 273^\circ\ 01' \\
\Omega &= 320\ \ 49 \\
i &= 141\ \ 25 \\
q &= 0.1914
\end{aligned}
$$

The residuals for the middle place being,

$$\text{Observed} - \text{Comp.} \begin{cases} \cos\beta'.\,\Delta\lambda' = & -0'.02 \\ \Delta\beta' = & -0\ .04 \end{cases}$$

From these preliminary elements an ephemeris was constructed, as follows:

November 20.5	α 13^h	52^m	14^s	δ	−	0°	$7'.7$
24.5	14	2	52		−	2	36 .3
28.5	14	16	27		−	5	43 .1
December 2.5	14	34	52		−	9	45 .7
10.5	15	45			−	22	
18.5	18	15			−	31	
26.5	19	10			−	23	

Gr. m. t.

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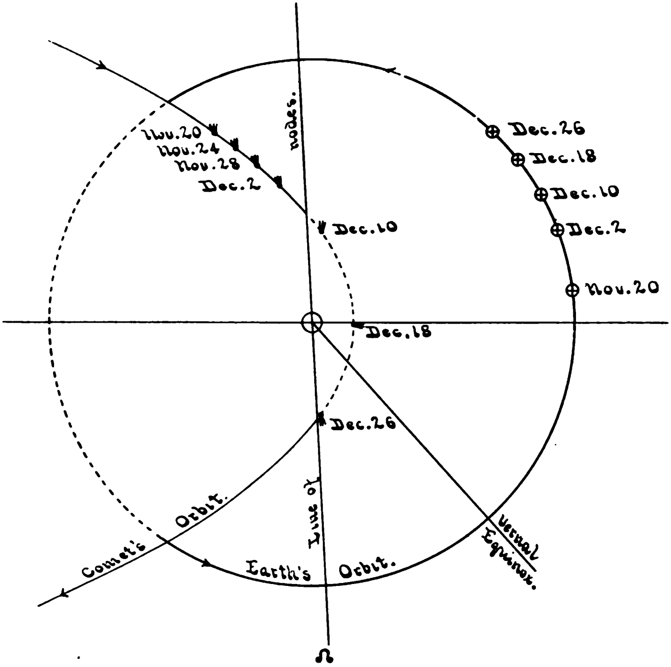
Orbit of Comet c 1895. (Perrine.)



A comparison of recent observations shows that the comet is following this ephemeris very closely. However, a new orbit will be computed shortly from observations separated by longer intervals of time, and from which a more accurate and extended ephemeris will be constructed. The accompanying diagram represents an orthographic projection of the comet's orbit on the plane of the ecliptic, and shows the positions of the comet in its orbit at different dates, and the corresponding places of the Earth in its orbit.

An inspection of the diagram shows how much more favorably the comet will be situated before its perihelion passage on December 18th than after. The Earth and comet approach each other until about December 13th, when they begin to separate.

The position of the comet's orbit is such that, about December 16th, it becomes an evening object; but, on account of its great southern declination, it will be badly located for observation. It will not recede far from the Sun, and about January 11th will again become a morning object. It will then be separated from us for some time by about the diameter of the Earth's orbit, and will be fainter than before perihelion. The comet has grown rapidly in brightness since discovery, and became visible to the naked eye on November 26th.

Mr. COLTON has secured photographs at every available opportunity. These show an increase in length of tail from about one degree on November 18th to five degrees on November 26th. Besides the main tail, there is a shorter one to the north, making an angle of about thirty degrees with the former. This short tail is the brighter of the two.

Professor CAMPBELL has examined the spectrum both visually and photographically, and finds the usual type; i. e., a faint continuous spectrum due to *reflected* light, and bright bands and lines showing the presence of incandescent carbon and nitrogen.

C. D. PERRINE.

LICK OBSERVATORY, December 1, 1895.

NEW ELEMENTS OF COMET *c* 1895 (PERRINE).

The following elements of Comet *c* 1895 are based upon Mr. PERRINE'S observations, made November 17th, 24th, and December 1st.

$$T = \text{G. m. t., 1895 Dec. } 18.32570$$

$$\left.\begin{array}{l} \omega = 272^\circ\ 35'\ 38''.0 \\ \Omega = 320\ \ 26\ \ 19\ .1 \\ i = 141\ \ 39\ \ 22\ .6 \end{array}\right\} 1895.0$$

$$q = 0.192253$$

$$\text{O} - \text{C:}\ \cos\beta'\,\Delta\lambda' = -\,1''.9;\ \Delta\beta' = -\,2''.1$$

W. W. C.

A MEDIEVAL GUESS AT THE ORIGIN OF THINGS.

Professor HENRY G. HANKS, of San Francisco, sends the following extract:

> "In very deed (that I may expound the matter in a few words) I found all things that are generated in the bowels of the mountains to be infused from the superior stars, and take their beginning from them in the form of an *aqueous cloud*, fume, or vapor, which for a very long time fed and nourished by the stars, is at length educated to a tangible form by the elements. Moreover, this vapor is dried, that the wateriness may lose its dominion and the fire next by the help of the air retain the ruling power. Of water-fire and of fire and air, earth is composed."

This paragraph is taken from "BASIL VALENTINE, his Triumphal Chariot of Antimony, with annotations by THEODORE KIRKRINGIUS," London, 1678, (page 145), which is a translation from the original work, *Currus Triumphalis Antimonii* (XV. century).

THE NEW OBSERVATORY OF HEIDELBERG.

A private letter from Professor MAX WOLF notifies that considerable progress has been made in the buildings of the new Heidelberg observatory. The institution is built on the summit of the *Konigstuhl*, 570 metres above sea-level, and 460 metres above the flat land near the river. The buildings are of stone; the dwelling-house is already under cover; the astrophysical laboratory is nearly finished; the tower for the astrophysical observatory (Professor WOLF) and the astronomical observatory (Professor VALENTINER) are about half-finished (November, 1895).

E. S. H.

ASTRONOMERS PREPARING FOR A VOYAGE TO JAPAN.

NEW YORK, December 3.—Professor DAVID TODD, of Amherst College, was aboard ARTHUR JAMES' schooner-yacht *Coronet* to-day, attending to the stowing away of the astronomical apparatus which he and his associates will make use of in their observations of the total eclipse of the Sun, on August 9th, from Akeshi, on the Japanese island of Yezo. The greater part of the apparatus which the *Coronet* will carry around the Horn on her trip to San Francisco, where Mr. JAMES and Professor TODD and their friends and fellow-workers will board her, was put away in the hold, and the rest of it was placed in the cabin.

The schooner will sail Thursday, and when the dispatch comes from San Francisco that she has arrived there, the members of the expedition will leave the East by rail to start from the Golden Gate on their cruise of several thousand miles over the Pacific Ocean.—*S. F. Chronicle.*

A SECOND CHAPTER OF HELIUM.

Three months ago we recorded the exultation of astronomers over the identification of "Helium"—the "running to earth," as Lord Kelvin neatly expressed it, of the problematical element which makes itself so conspicuous in the spectrum of the solar prominences, and in many notable stars and nebulæ, while keeping most furtively concealed on our own planet. For a time some justifiable skepticism as to the validity of the identification remained, on the ground that a single line in the spectrum, even D_3 itself, could hardly give evidence sufficient to warrant a confident conclusion; but the lingering incredulity was soon dissipated when observers found in the spectrum of the new gas half a dozen other lines corresponding to certain lines in the prominence-spectrum which had remained hitherto unidentified, like D_3 itself, and had been supposed to have the same origin.

It was with something like consternation, therefore, that in June astronomers received the announcement from RUNGE, an eminent German spectroscopist, that, in the spectrum of the terrestrial gas, the line assumed to be identical with D_3 is *double*, and that unless D_3 itself is also double in the chromosphere spectrum the identification must be given up. Of course, the solar observers at once began to study the line most carefully,—at first without success; but before the month closed a brilliant prominence made its appearance, and in its spectrum Professor HALE found the line double, just as it ought to be. The observation was difficult, but others—in fact, all who had spectroscopes of sufficient power—soon confirmed it; so that now there can remain no possible doubt on the question of identity.

Professor RAMSAY has detected small quantities of helium in several other minerals besides the uraninites, in which it was originally discovered. Its presence in meteoric iron is especially interesting, where it is found associated with the hydrogen and and the various carbon gases which have long been known to be "occluded" in these celestial visitors.

The new element turns out to be, next to hydrogen, the lightest of all known gases, its density being about one-seventh that of air, or two on the hydrogen scale. Like hydrogen, it is never found free in our atmosphere; but unlike hydrogen, which in its combinations with oxygen and carbon is most abundant upon the earth, helium is extremely rare, and seems, like its associate, argon, to be almost without chemical affinities. Certain apparent coincidences between lines in the spectrum of argon and of this terrestrial helium seem to Professor RAMSAY to indicate either some third still unknown gas associated with argon and helium in the minerals from which they are obtained, or else some close and unexplained physical relation between the two.—Professor C. A. YOUNG, in *The Cosmopolitan*, November, 1895.

VARIABLE STAR CLUSTERS.

Professor SOLON I. BAILEY, in charge of the station at Arequipa, maintained by this observatory, has discovered from an examination of the photographs obtained by him of certain globular clusters, that they contain an extraordinary number of variable stars. This is not a general condition of stellar clusters, however; for in others similarly examined by Professor BAILEY, no variable stars have been found. The photographs used in this discussion were taken at Arequipa with the BOYDEN thirteen-inch telescope. In the cluster in *Canes Venatici*, MESSIER 3 (N. G. C. 5272), no less than eighty-seven stars have been proved to be variable from an examination of fifteen photographic plates. The change in every case is certain, and has been confirmed independently by Mrs. FLEMING and the writer from an examination of six of these plates. Sometimes the variation amounts to two magnitudes or more, and sometimes it does not exceed half a magnitude on the plates which were used for its confirmation. No star was included in this count, if either of the three observers doubted the variation. Nine other stars were found to be variable by Mr. BAILEY, but they are not included, since they did not show sufficient change on the plates used in confirmation. In like manner, from an examination of seventeen plates, Mr. BAILEY found forty-six variables in the cluster MESSIER 5 (N. G. C. 5904), which were confirmed on five plates. Fourteen other stars in this cluster are also probably variable, but have not yet been confirmed. This cluster is frequently described as 5 *M Libræ*, probably following SMYTH. It is actually in *Serpens*, and very near 5 *Serpentis*. Two variable stars have been confirmed in N. G. C. 7089, from an examination of six plates; three in N. G. C. 7099, from five plates; five with small range in N. G. C. 362, from three plates; and four in N. G. C. 6656, from three plates. On the other hand, a similar examination of two plates of each of the clusters N. G. C. 6218, 6397, 6626, 6705, and 6752 failed to detect a single variable star, several hundred stars in each case apparently having exactly the same brightness on both plates. As, however, these plates were taken within a few days of each other, only variable stars of short period could have been detected on them. In general, no variables have been found within about one minute of the center of the clusters, on account of the closeness of the stars. None of these variables are more than ten minutes distant from the centers of the clusters. In N. G. C. 5904, a circle 110 inches in diameter contains sixteen stars, six of which, or nearly forty per cent., are variable. In the entire cluster, about 750 stars were examined, and 46 found to be variable, as above stated; so that they form about six per cent of the whole. Of all the stars visible to the naked eye, less than one per cent were variable.

In 1890, Mr. PACKER discovered two variable stars in the cluster N. G. C. 5904. (*English Mechanic*, Vol. LI, 378; *Sidereal Messenger* IX, 380, 381; X, 107.) One of these variables was discovered independently by Mr. BAILEY, but is not included in the above lists. Several stars in this cluster were thought to be variable by Mr. COMMON. (*Monthly Notices*, L, 517; LI, 226). One of them is too near the center; the others too distant to be included in the above discussion. The variable star discovered in the cluster N. G. C. 5272 by the writer, in 1889, is also too near the center to be included.

Some of these variable stars have short periods, not more than a few hours. For instance, one of them, No. 12, which precedes the center of N. G. C. 5904 by about three minutes of arc. Five photographs of this cluster were taken on July 1, 1895, at intervals of an hour. The corresponding magnitudes of the variable as derived from these plates, are 14.3, 13.5, 13.8, 13.9, and 14.3. Four plates, taken on August 9, 1895, also at intervals of an hour, gave the magnitudes 14.2, 14.6, 14.8, and 15.0.

Right Ascensions and Declinations cannot conveniently be used for indicating the individual stars in close clusters. They can only be found readily from photographic or other charts on which they are marked. Such charts are now being prepared for publication in the Annals of the Observatory. Meanwhile marked photographs will be sent to such astronomers as may wish to study them. EDWARD C. PICKERING.

November 2, 1895.
HARVARD College Observatory, Circular No. 2.

TRANSLATION OF ARATUS.

Mr. C. LEESON PRINCE, Director of the private observatory at Crowborough, Sussex, England, has translated the poem of ARATUS,—"The Phenomena"—and has had it privately (and very neatly) printed and bound under the title, *A Literal Translation of the Astronomy and Meteorology of ARATUS*, with some bibliographical remarks. Lewes, 1895, quarto, pp. viii, 82. The edition is limited, and has been distributed to correspondents of Mr. PRINCE. E. S. H.

ELEMENTS AND EPHEMERIS OF COMET *a* 1895 (SWIFT), BY PROFESSOR A. O. LEUSCHNER.

"The following elements computed by Professor A. O. LEUSCHNER, assisted by Mr. W. H. WRIGHT, from observations made by Professor E. E. BARNARD, August 21st, 22d, and 23d, were received by mail. Although telegraphed from California, August 26th, their publication was delayed, owing to three wrong words in the telegram:

$$T = 1895 \text{ August } 16.4510, \text{ G. m. t.}$$

$$\left.\begin{aligned} \omega &= 164^\circ\ \ 1'\ \ 33'' \\ \Omega &= 172\ \ 32\ \ 40 \\ i &= 3\ \ 38\ \ 4.5 \end{aligned}\right\} \text{Mean Equin. } 1895.0.$$

$$\log q = 0.142716$$

Correction to Ephemeris, September 3d (from observation by Professor Boss, Albany), was $+15^s$ and $-0'.7$." —From the *Astronomical Journal*, No. 355, October 2, 1895.

Note on the foregoing, by Edward S. Holden.

The phrase "three wrong words in the telegram" does not make it clear that the message in question was correctly sent from California, as it should do. As a matter of fact, the cipher telegram was correctly written at the Lick Observatory on August 26th (by Professor Campbell), it was telephoned to San José and correctly received there, and it was correctly transmitted eastward by the San José office. Professor Leuschner was notified of the facts as given above by letter dated September 2d,* immediately after receiving information from the Harvard College Observatory that the message as delivered to them on August 26th contained three wrong words.

A NEW STAR IN *CENTAURUS.*

A telegram just received from Professor Pickering, of the Harvard College Observatory, states that Mrs. Fleming, of that observatory, has discovered a "new star" in Right Ascension $13^h\ 34^m$, Declination $-31°$. It is described as eleventh magnitude, fading. It is 30 seconds north-following the nebula New Gen. Catal. 5253.

Lick Observatory, 1895, December 17.

The Herschels and Modern Astronomy. By Agnes M. Clerke. (The Century Series.) Cassell & Co., London, 1895. 16mo, pp, 224, with three portraits.

Under this title, Miss Clerke has ten chapters, five of which deal with the career and influence of Sir William Herschel, one with the life of his sister Caroline, and four with the life and labors of Sir John. Miss Clerke has, of course, consulted all previously published information, and has also had access to many of the unpublished papers of the family Like all others who have had occasion to study the writings of these astronomers (and who has not?), she notes the "conspicuous gap in scientific literature," due to the fact that no collection of their works is yet available to students. Their writings must still be sought in the volumes of the *Philosophical Transactions* of the Royal Society from 1780 onwards, and these volumes are now rare and costly. Miss CLERKE's little book will be found both useful and interesting, and, in so far, it helps to fill the gap referred to. Is it too much to hope that a splendid edition of the works of these great Englishmen may some day be given to the world? Such a publication, properly edited, would be welcomed everywhere.

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* Thirty days before the publication in the *Astronomical Journal.*

E. S. H.

CONSIDER THE HEAVENS: A POPULAR INTRODUCTION TO ASTRONOMY. By Mrs. William Steadman Aldis. The Religious Tract Society, London, 1895. 8vo, pp. 224, with thirty-one illustrations.

The scope of this introduction to astronomy is indicated by its title and in the following extract from the preface: "The book has been written for those who are quite ignorant of this great subject, and especially for such as have not much time for any study, in the hope of bringing into lives of scanty leisure a fresh, fascinating, boundless source of interest." Mrs. ALDIS' manner of presenting the subject is original and vivid, the facts and the methods of the science are accurately recounted and described, and the book will, no doubt, quite fulfill its purpose. E. S. H.

CORRECTION.

The last two sentences of Mr. JOHN TEBBUTT'S communication on page 219, No. 43, of these *Publications*, were wrongly set up by the printer. They should read thus:

"The above is the greatest discrepancy I have remarked between theory and observation since 1866, when I commenced the systematic observation of Jovian eclipses. An error of 10^m 14^s was observed in the *English Nautical Almanac* time for the eclipse-disappearance of May 30, 1880."

Minutes of the Meeting of the Astronomical Society of the Pacific, held in the Lecture Hall of the California Academy of Sciences, November 30, 1895.

The meeting was called to order by President Burckhalter. The minutes of the last meeting, as printed in the *Publications*, were approved.

The Secretary read the names of new members duly elected at the Directors' meeting.

The following papers were presented:

1. Double-Star Measures, by Mr. R. G. Aitken, Lick Observatory.
2. Review of Solar Observations, 1891-1895, by Mr. David E. Hadden, Alta, Iowa.
3. Recent Discoveries concerning Helium, and their bearing upon Astronomical Problems, by Mr. Edwin B. Frost, Dartmouth College, Hanover, N. H.
4. Bright Projections observed at the Terminator of *Mars*, in 1894, by Professor W. W. Campbell, Lick Observatory.
5. Planetary Phenomena for January and February, 1896, by Professor Malcolm McNeill.
6. Review of T. G. Elger's *Moon*, by Mr. C. M. Gaudibert.
7. The New Terrestrial Element, Helium, by Professor W. J. Hussey, of Stanford University.
8. The Circulation of the Atmosphere of Planets, by Marsden Manson, C. E., of San Francisco.

Papers Nos. 7 and 8 were read by the authors.

Mr. Burckhalter gave an account of Perrine's comet, and exhibited three photographs of the same, taken at Lick Observatory by Mr. Colton.

The thanks of the Society were returned to the California Academy of Sciences for the use of the Lecture Hall.

Adjourned.

Minutes of the Meeting of the Board of Directors held in the Rooms of the Society, November 30, 1895, at 7:30 p. m.

President Burckhalter presided. A quorum was present. The minutes of the last meeting were approved. The following members were duly elected:

List of Members Elected November 30, 1895.

(Election to take effect January 1, 1896.)

Miss Martha H. Munro	542 Massachusetts Ave., Boston, Mass.
Mr. Julius Stone*	Care of the Ohio Central Fuel Co., Columbus, Ohio.
Mr. W. P. Wallheiser	Bedford, Indiana.

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* A star signifies Life Membership.

It was

Resolved, That any institution that has failed to forward publications in return for those received from this Society is respectfully requested to communicate with the Secretary if a continuance of the interchange of publications be desired.

A communication was received from the California Academy of Sciences granting the use of the Lecture Hall of the Academy for the the meetings of November 30, 1895, January 25, 1896, and March 28, 1896.

Adjourned.

OFFICERS OF THE SOCIETY.

CHAS. BURCKHALTER (CHABOT Observatory, Oakland), ... *President*
W. J. HUSSEY (LELAND STANFORD Jr. University, Palo Alto, Cal.),
E. S. HOLDEN (LICK Observatory)
O. VON GELDERN (819 Market Street, S. F.), . *Vice-Presidents*
C. D. PERRINE (LICK Observatory), ... *Secretary*
F. R. ZIEL (410 California Street, S. F.), ... *Secretary and Treasurer*

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Committee on Publication—Messrs. HOLDEN, CAMPBELL, BABCOCK.

Library Committee—Mr. MOLERA, Miss O'HALLORAN, Mr. BABCOCK.

Committee on the Comet-Medal—Messrs. HOLDEN *(ex-officio)*, SCHAEBERLE, HUSSEY.

OFFICERS OF THE CHICAGO SECTION.

Executive Committee—RUTHVEN W. PIKE.

OFFICERS OF THE MEXICAN SECTION.

Executive Committee—CAMILO GONZALEZ, FRANCISCO RODRIGUEZ REY, AGUSTIN ARAGON

NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the *calendar* year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our book-keeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific 819 Market Street, San Francisco.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 819 Market Street, San Francisco, who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed rests with the writers, and is not assumed by the Society itself.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend any or all of the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific" at the rooms of the Society, 819 Market Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

PUBLICATIONS ISSUED BI-MONTHLY.

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